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THE BIGGER THE ORGANISATION

"We still know very little of the forces that determine whether particular groups of men will collaborate with one another and their managers." These words are taken from a paper by Professor R. W. Revans which was given to the recent conference of the Institution of Production Engineers, reported in this issue. Searching for a law or laws that would help us to understand industrial behaviour, Professor Revans finds that there is strong evidence to show that the larger the establishment, in terms of numbers employed, the more trouble there is with strikes, absenteeism, and accidents.

His first illustrations are taken from figures relating to the Yorkshire and South Wales coalmines. He gives the tonnage lost per man in disputes, i.e., strikes and go-slows. The mines are grouped according to the numbers employed—from below 500 to above 2,500, in steps of 500. The lost tonnage increases from 5·94 for the small mines to as much as 22·70 for the large ones in Yorkshire; and much the same is found in the Welsh pits. Strikes affecting a whole coalfield were excluded in order to reveal the extent to which the men in the individual mines will withdraw from their work over some disputed issue arising in their own mines.

It is usually contended that the explanation of this size effect is to be found in the likelihood that an agitator who wants to stir up trouble or exploit the grievances of other men can do so more readily in a large organisation. He can work under cover and the managers find it more difficult to deal with him or to counteract his influence. Professor Revans finds that this explanation does not fit the facts. In particular, disputes over wages—which agitators would tend to choose as the reason for agitation—are fewer, in relation to disputes over other matters, in the larger coalmines than in the smaller ones.

The size effect is confirmed by figures for accidents—accidents not only in coalmines but also in quarries, and even in American hospitals. For the South Wales mines it is found that the risk of having an accident if one is a miner in a large mine is about eight times as great as the risk of an accident in the same period of time if one works in a very small mine. (The degree of mechanisation of a mine might be thought to affect these statistics, but Professor Revans shows that it does not invalidate the conclusion relating to size effect). "It is," as he says, "something about working in the large community that must account for the liability." The accident rates in nearly 5,000 American hospitals, for the year 1953, provide striking confirmation. The nurse, laundry worker, ward orderly or other employee is six times as liable to have an accident in a large hospital as in a small one.

All these figures can be put on a graph. Using ordinates of accident rate per million man-hours, and of size by average number of persons employed arranged on a logarithmic scale, straight lines are produced in every case. The accident rate is of course lower in the hospitals than in the quarries, and lower in the quarries than in the mines, but they are all straight lines, and the size of organisation at which the accident rate becomes zero is that employing one person. Professor Revans wonders whether therefore accidents are almost wholly "social events", caused by trying to get people to work together. He recalls Sigmund Freud's suggestion that people have accidents only when they want to have them; that is, when they find themselves in situations that they want to get out of. A study of absenteeism shows the same characteristic: the percentage of absenteeism in the large mines is much worse than that in the small. In the case of girls at telephone exchanges, too, their attendance is better in the small exchanges.

These findings of Professor Revans—based as they are on all the statistics available to him—are highly significant; not for reaching the obvious and crude conclusion that large organisations should be avoided, but because they point to the possibility of discovering the law or laws which he believes will throw light on the highly complex pattern of industrial relations. He rejects the argument that because the pattern is complex it is not possible to formulate a law. He derives comfort and hope from the fact that Darwin arrived at his theory of evolution from natural selection by collecting an immense amount of evidence about how various organisms live. The pattern was certainly complex, but Darwin detected a common thread.

The statistics which Professor Revans puts forward in his paper are not of course the only statistics which will have to be examined, but they offer strong grounds for believing that eventually some scientific sense will be made of the conflicting mass of events and interpretations which clutter up the field of industrial relations. Professor Revans' tentative conclusion is that the explanation of the size effect is to be found in the increasing difficulty of communication with increasing size of organisation. He is well placed to suggest a conclusion, having had considerable experience in education and

with the National Coal Board, but the evidence he has collected points to the possibility of finding an explanation that is more fundamental to the nature of man and society.

* * *

Plain Words

There are many ways a public authority can exert effective control over the private individual or concern. The blunt instrument of the directive is the least invidious, for being explicit it is open to criticism and appeal. Less direct, but only thinly disguised, is control by manipulation of the purse strings; there is the danger, for example, that ultimate control of the universities can fall more and more into the hands of the Treasury. But in the last few years a new form of control has reared its head—control by withholding information.

Recognising that Britain is limited in her resources, the United Kingdom Atomic Energy Authority has taken a decision to concentrate on a reactor system which has shown a considerable initial success, and offers quite good prospects for the future. But gas cooling, which is fundamental to this system, requires a comparatively large circulating volume, so that even with enriched fuel a gas-cooled reactor can only be economic in the larger, and therefore more powerful sizes. Now if a private company sees that for the export market, so important to Britain, the smaller reactor offers greater chance of success, it may wish to undertake research and development work on one of the systems which show promise in the lower power ratings, and unless it is prepared to start entirely from scratch, the company will depend for basic data on the U.K.A.E.A. Thus the Authority is in a position to discourage such a company by freeing information only in accordance with official reactor policy. To avoid this obstacle certain companies have already made agreements with American firms, but others have been compelled to fall into line, or to see the fruits of work already accomplished postponed for an indefinite period. Indeed, by the time permission is given for development to go ahead on liquid fuelled systems, the Americans may have cornered the market, or fission reactor studies may have given way to large-scale fusion research.

How does the U.K.A.E.A. exercise control? Companies are granted access permits in accordance with what are divined to be their requirements. These permits cover only limited sectors, so that a firm engaged on a gas-cooled reactor project can only obtain information on that subject, and little progress can be made in a new field without application to the Authority for a fresh permit. Privacy is thus impossible, and excursions in unorthodox directions can be quickly frustrated. The access permit has the further disadvantage that cross-fertilisation between different fields of study cannot take place.

Though Britain may need to concentrate her effort, surely the company which is prepared to risk its capital on a rival project—even in the face of advice—should be allowed to do so. Otherwise atomic paternalism may become so entrenched that individual enterprise will be stifled. Classification, which is the agent of this paternalism, is sand in the works of progress; ideas held incommunicado become obsolete before they can be put to use, and facts that may stimulate original thought remain sterile in secret files. Research is duplicated in half-a-dozen hermetically sealed cells, while the work of classification creates a whole new bureaucracy. The comic aspect of Twentieth Century security is illustrated by the recent American statement on declassification policy, which included the telling comment: "The declassification guide is itself classified." But its tragic aspect dominates: most menacing of all is the power it places in too few hands.

The Crab Nebula is one of the few intense radio stars that is also a bright optical object. As such it is of considerable importance to the astronomer. The 1,800 ton steerable telescope at Jodrell Bank will be used to study it, and other nebulae located at distances approaching the limits of the universe. The Crab Nebula is thought to be the remains of a star that exploded in the 11th Century A.D. (The photograph is reproduced by kind permission of the Mount Wilson and Palomar Observatories.)

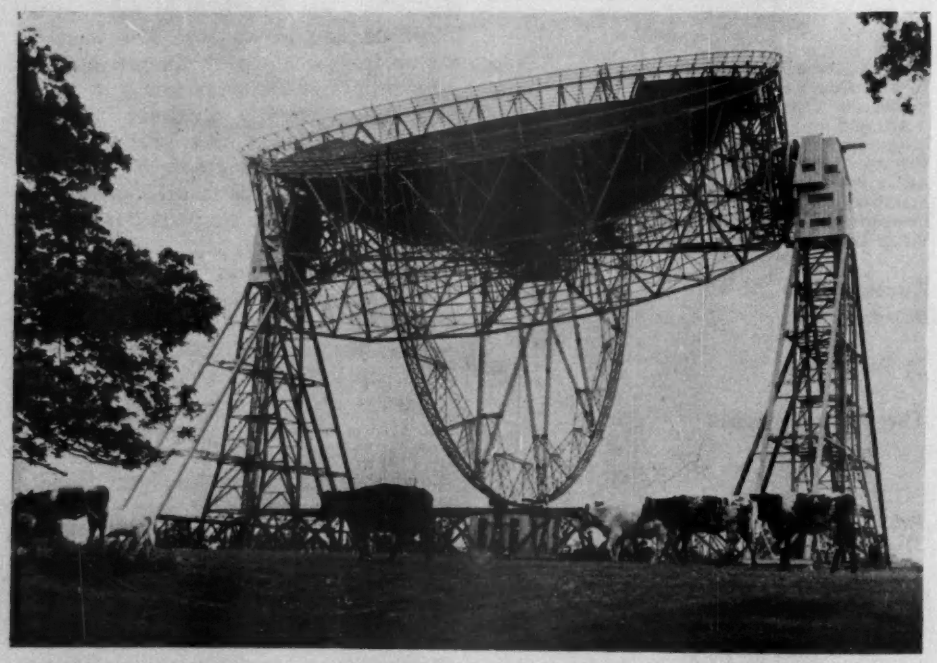
AIMING 1,800 TONS AT A STAR

The 1,800 ton structure nearing completion at Jodrell Bank—the radio astronomy centre just south of Manchester—is the world's largest completely steerable radio telescope. It is owned by the University of Manchester. Used with improved radar equipment it should be able to detect aircraft flying beyond the orbit of the moon. It may be able to bounce radio waves off the planets, and so discover more exactly the measurements of the Solar system. But these will not be its chief uses.

Professor A. C. B. Lovell is in charge of research at Jodrell Bank. For him the telescope is the realisation of a ten year old dream. Looking back over those years, Professor Lovell remarked "Everything that has happened in radio astronomy has underlined the importance of designing a telescope of this size." He went on to outline the main work of the telescope. "At the present time not more than a dozen of the extra-galactic nebulae have been studied. We hope to extend this number quite quickly by using this telescope. The sky is full of localised radio sources, the majority—which amount to several thousand—do not have an optical counterpart. The evidence is that they are very remote indeed. A large amount of time will be taken up with the investigation of these sources."

Thus the telescope will be studying the limits of the universe. Professor Lovell discussed some aspects of the programme in greater detail. He said that it was hoped that a count would be made of radio sources at great distances. Such a count would test the validity of the various theories on the creation of the universe. The telescope will also be of great value in the study of meteors. However, Professor Lovell emphasised "We will reserve it for situations where its great potential can be fully used," adding, "Nevertheless we will use it for special events in the International Geophysical Year." In this context tracking of the American earth satellite and an attempt to detect corpuscular streams from the sun were mentioned.

The justification for the great steerable instrument at Jodrell Bank arose from the important results got from a "fixed" reflector 218 ft. in diameter. This was in the form of a paraboloid constructed of thin wire mesh stretched on tubular



The fully steerable radio telescope at Jodrell Bank nears completion. This view shows clearly the large circular stabilising girder, or bicycle wheel, that extends behind the bowl. Gears housed at the tops of the two towers rotate the bowl in elevation.

scaffolding. The fixed reflector was constantly observing a great disc of space, by virtue of the earth's rotation.

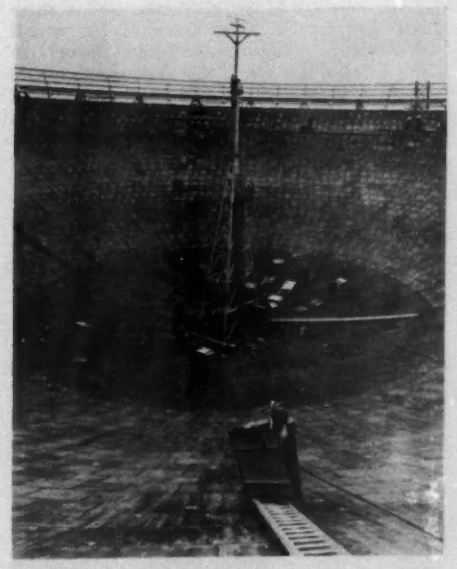
The possibility of producing a fully steerable telescope was considered. It was to have a reflector as large as could be provided within reasonable limits of expenditure. The essential requirements were that the reflector should be sufficiently accurate to deal with radio wavelengths of the order of one metre, with a corresponding accuracy of directional control. It was decided that the project was feasible. Later the specification for the accuracy of the bowl was made more rigorous so that the 21 cm. spectral line of hydrogen could be studied.

The telescope takes the form of a paraboloidal reflecting surface 250 ft. in diameter cradled in a bowl of structural steelwork that is 11 ft. deep at the centre of the bowl and 73 ft. deep at its outer edge. It was found that it was easier to produce an accurate curved shape by using bent steel plates for the bowl than by straining wire mesh. From the outset the engineers decided to build the telescope entirely of steel. Steel has the greatest strength per unit of cost. It has a relatively low coefficient of expansion—a vital consideration if accuracy in shape is to be maintained without the use of special temperature compensating devices. Steel has a much higher modulus of elasticity than aluminium alloys; a factor of great importance in the design of the supporting structure of the reflector bowl, which suffers large stress changes during its revolution. The greater weight of steel adds stability to the whole apparatus.

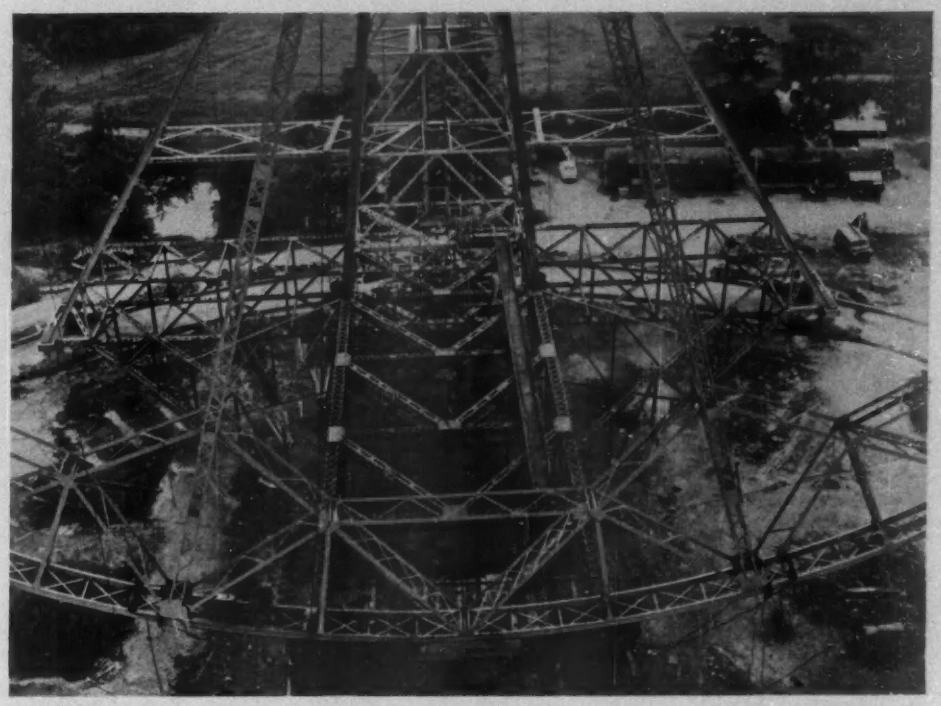
The bowl structure weighs about 800 tons and pivots between two steel lattice towers 185 ft. high. In their turn the towers rise from a system of deep trussed girders. Bogies support the substructure, which weighs about 1,000 tons. The bogies travel on a circular railway track 352 ft. in diameter.

Radio waves reflect from the concave surface of the bowl and focus on an aerial at the top of the lattice tower that rises 55 ft. from the lowest point of the bowl. Below the bowl hangs a laboratory. It is always on an even keel, even with the bowl completely inverted. To change the aerial the bowl is inverted and the aerial lowered by winch to a platform on top of the motor-generator house in the centre of the diametric girder. Husband and Company, consulting engineers, designed the telescope structure. The United Steel Structural Company, Limited, a subsidiary of the United Steel Companies, Limited, supplied the steel.

"The major problem has been to design and make machinery that moves extremely slowly—



Some practical idea of the size of the 250 ft. bowl can be grasped from this illustration. The tower in the centre carries the aerials. They are located at the focus of the paraboloid.



From the level of the trunnions the construction of the diametric box beam and the location of the four outer wind-carriages can be seen. The pneumatic tyres bearing on the circular girder in the foreground form an effective wind damping device.

slower than the hour hand of a watch," explained Mr. H. C. Husband. The axles of the bogies are all radial to the rail circle; the rollers are truncated cones that, if extended, would have their apex at the centre pivot. Such efforts to reduce friction have met with success said Mr. Husband: "We are turning it with a very small fraction of the power that is necessary for bad wind conditions." He added that by using a friction drive on the track, a smoother drive had been obtained than could be got by using racks and chains.

When moving at maximum speed the telescope can make one complete rotation on its track in 18 minutes. The bowl makes a rotation in 15 minutes. The telescope can just move fast enough to track the proposed earth satellite. Normal speed of movement is only a fraction of this. The accuracy of the horizontal and vertical positioning is $\pm$ 12 minutes of arc. At a wavelength of 1 metre the beamwidth of the telescope will be about 1 deg. The power gain will be greater than 16,000.

It was subsequently decided to add to the bowl structure a stabilising girder on the axis vertical to the centre line through the trunnions. The girder has similar characteristics to a bicycle wheel, having spokes radiating from the centre of gravity of the underside of the bowl. It is 280 ft. in diameter and gives greater stability and better control, especially under high wind conditions; the pneumatic tyres that bear on it make an effective wind damping device.

A normal foundation could not carry the heavy and intermittent loads imposed by the dead weight of the structure, its rotation, and the wind pressure. During the early part of 1952, therefore, before the precise location of the telescope had been determined, the Cementation Company, Limited, investigated the ground conditions. A number of test borings, up to 86 ft. deep, were sunk over a fairly wide area. Put down on a site some distance away from the final position of the telescope, the preliminary borings showed considerable variation. Comparatively soft upper beds of clay and generally waterlogged sand were underlain by a stratum of hard dry red marl. The horizon of the hard marl was very irregular and the standing water level in the ground was not constant.

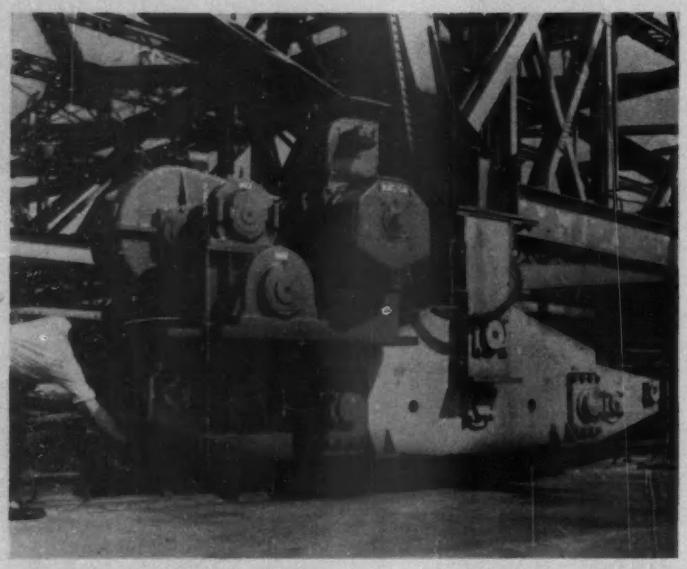
It was clear that the foundation to the telescope would have to use a system of reinforced concrete piles, sunk to the depth necessary to get a toe bearing in the marl. Advantage could also be gained from the frictional value of the measures overlying the marl. The consulting engineer drew up a scheme for 152 bored concrete piles. Each pile measured 19 in. in diameter and was designed for a calculated maximum load of 76 tons.

On September 2, 1952, the winch of the first piling rig started. By May 21, 1953, the piles were in. As a result of the inconsistency in the horizon and the hardness of the marl, the depths of the piles vary widely. The longest reaches 90 ft. below ground level, the shortest 37 ft.

The piles support a reinforced-concrete ring beam. W. J. Whittall and Son, Limited, were the contractors for this beam and for the central thrust block—together with its connecting access cable subway from the control building. Of the 152 piles, 146 support the ring beam and six the centre thurst block. The ring beam consists of an inner and outer section of equal dimensions, namely 6 ft. wide by 3 ft. deep, connected by an 8 in. thick concrete slab. The piles stand in circles with diameters of 352 ft. 11$\frac{1}{2}$ in. and 319 ft. 2$\frac{3}{4}$ in. The centre thrust block measures 24 ft. in diameter and goes 10 ft. down into the ground. It has an annular chamber, which can be used as a laboratory, in which the cable duct ends. The duct has 9 in. reinforced concrete walls and floor, and a 10 in. roof. Racks carry the various cables. If you are less than 6 ft. 2 in. tall the duct is a good way of travelling between the control room and the telescope.

The ring beam carries the precision rail trackwork that the telescope goes round on. Permissible tolerance in line and level of the track during installation was $\frac{1}{16}$ in. It consists of two circles of twin rail of 109 lb. flat-bottomed section. The diameters are 352 ft. 9$\frac{1}{2}$ in. and 319 ft. $\frac{1}{4}$ in., to the centres of the twin rails, the rails in each case being at 7 in. centres. Laying of the trackwork was by Thos. W. Ward Limited; fabrication of the track was carried out by their subsidiary—Darlington Railway Plant and Foundry Company, Limited.

Twenty-four lengths of double rail make up each circle. At each joint the ends are scarfed at an angle of 30 deg. The cut extends 11 in. across the rail flange and a gap of slightly less than $\frac{1}{8}$ in. exists at the rail joint. As design dictated that the rail joints occur at specific points around each circle, the rail lengths vary,



There are four driving bogies such as this. Owing to the very low speeds at which the motors normally run, forced ventilation is necessary. The total overall reduction from motor to track is 185/1.

but most of the rails are 42 ft. 1⅛ in. or 46 ft. 6⅛ in. long.

The inner rail on each circle is mounted on mild steel packing pieces ⅜ in. thick. The packing pieces lie the length of the baseplate but only extend the width of the rail flange, that is 5½ in. Standard rail clips are used on the outside flanges of the twin rails, but the inner flanges are held by a specially made double clip. (The rail flanges stand 1½ in. apart at this position.) To allow for any settling of the track on the concrete formation, the countersunk bolts securing the mild steel clips to the baseplate are made 1 in. longer than normal. Thus additional packings can if necessary be put between the rails and the baseplate. To set the track to the fine limits required, cast iron wedges were used—six per baseplate. The wedges were supplied 3 in. wide, 6 in. long, tapering from 1⅞ in. to 1¼ in.

The main structure of the telescope was erected by Cozens and Sutcliffe Limited under the supervision of the United Steel Structural Company, Limited. Most of the work was done with two 15 ton Scotch derricks. They were mounted on gabbard towers 120 ft. high equipped with railway bogies. Movement in two directions was possible by jacking up the bogies and turning them through 90 deg. From time to time crawler and pneumatic-tyred mobile cranes with capacities up to 15 tons and jib lengths of 90 ft. supplemented the main cranes. It was decided that the bowl would be supported during erection on 12 towers built up in tubular scaffolding structure.

In the fabrication shops, before work on site started, a large number of templates had to be produced. Very careful setting out was required to establish the shape of the radial trusses in the bowl, because their top chord had to conform to the correct parabolic shape. Actual fabrication of the steelwork started in the shops during May, 1954. The main difficulty was that most of the structures were so large that they could not be assembled in the shops; it was necessary to rely almost entirely on the accuracy of the individual components. The main radial girders had to be dispatched piecemeal and assembled on site. Care was called for in the bending of the 2,200 angle-iron purlins for the interior surface of the bowl. Each one had to be correctly curved in two planes.

The most important piece of shop assembling was that of the trunnions in the girder that carries the bowl driving rack. The assembly had to be accurate when it was lifted 165 ft. to its position at the top of the towers.

Erection started in August, 1954. Construction of the diametrical girder on temporary supports was begun—working out from the centre pivot. At each end of the finished girder, chord girders were put in place; under these the rail bogies were fixed, as they came to the site. Erection and bracing of the towers followed.

The bogies were assembled in three sections on their tracks. There are four driving bogies and eight wind carriages—the former weighing 16 tons, the latter 13½ tons. Each of the driving bogies has an individual driving motor unit that drives four monorail track wheels. Spur idler gears couple each track wheel. To accommodate the radius of the track the spur gears are cut with a slight taper on the teeth. Four wind carriages travel the outer track, the remaining eight bogies move on the inner track.

The wheels have cast iron centres with forged steel tyres shrunk on. Each tyre is tapered. Each wheel of the bogies is mounted on two parallel roller bearings and one ball location bearing. The bearings were supplied by the Hoffmann Manufacturing Company, Limited. This firm also supplied the bearing for the centre pivot, made by the Davy and United Engineering Company, Limited. Comprising two castings, weighing jointly about 13 tons, the pivot serves to locate the revolving structure. It has a double-row roller journal bearing with a bore of 30 in., outside diameter of 42 in. and a width of 7¾ in. While this bearing controls the whole structure sideways, taking the wind load, a single ball thrust bearing carries a portion of the weight.

In October, 1955, erection of the scaffolding started. A high tower of tubular scaffolding falsework—Mills Scaffold Company, Limited, were the contractors—was built over the centre pivot. On top of the tower the steel spider forming the centre of the bowl was erected. By this time the trunnion bearings had been fitted on the towers enabling the centre of the bowl to be accurately aligned between them. The trunnions, rack girders, and the first portion of the bowl circumferential trusses were erected on more falsework at either tower. It was then possible to erect and adjust the first four radial girders connecting the two trunnion assemblies.

It was proved that the whole sub-structure was accurate and little difficulty was experienced in getting the correct setting for the critical starting point for the bowl steelwork. Work then began building out fan-wise on both sides of the bowl. Each crane worked independently and each panel point on the circumference of the bowl was supported on tubular falsework. The steelwork was finally closed on the outer edge of the bowl on September 12, 1956. It was unnecessary to adjust the length of any of the closing members.

One of the main features of the telescope is the mild steel skin with which the whole of the inside of the reflecting bowl is lined. Welding by the metallic arc process was adopted and the membrane is made up from 14 gauge steel plates, 3 ft. square. The manufacture and fixing *in situ* was carried out by Orthostyle Limited. Over 7,000 plates were used.

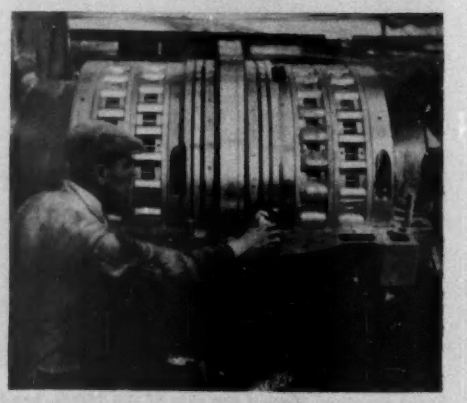
Expansion of the bowl is taken care of by the large thrust races in the main bearings. Hydraulic jacks give slight adjustment to the shape of the bowl. The tolerance for the position of the plates is ± ¼ in. In practice the framework makes it rather more.

The two trunnion roller bearings that support the reflector of the telescope were designed and manufactured by the Cooper Roller Bearings Company, Limited. The roller bearings, while not the largest made by the company, have the greatest load/diameter ratio of any made up to the present time. Each bearing can carry a radial load of 500 tons and an axial or thrust load in either direction of 125 tons. The bearings have a bore of 30 in. Each has four rows of rollers 2⅛ in. in diameter by 3¾ in. long, to carry the radial load. The inner and outer races are in two halves to the circle.

Two distinct sets of transmission gears have been installed, one to effect the movement of the bowl—the elevation gears; the others to rotate the structure on the steel tracks—the azimuth gears· Both sets were manufactured and installed by Alfred Wiseman and Company, Limited. One azimuth transmission set is mounted on each of the four powered bogies. The set consists of a standard double-reduction spur-gear unit followed by larger gears. The total overall reduction from motor to track is 185/1. Two sets of gears in tandem rotate the telescope bowl. Each gives an overall reduction of about 21,500/1.

Electrical power for the telescope is supplied by a Brush/Mirrlees Diesel generating set at 400/440 volts, 3 phase, 50 c.p.s. The Brush Electrical Engineering Company, Limited, were responsible for the manufacture, supply and erection of all the machines, control gear and reduction gear equipment that move the telescope. Also the company supplied the electronic equipment that converts the requirements of the telescope controller into movement of the driving motors. The control equipment can be considered as two identical sets. One drives the telescope in azimuth, the other drives it in elevation. Each movement is actuated by means of four variable-speed direct-current motors. A speed range of 10 to 1,000 r.p.m. is got by Ward-Leonard control. By weakening the motor field, variation between 1,000 and 1,500 r.p.m. is possible.

The four motors of each drive are connected electrically in series. Since they usually rotate at very low speeds, forced cooling is necessary. Power is supplied from a 175 kW direct-current generator driven by a slip ring type of induction motor. Two exciters operate in conjunction with the motor generator set. A control exciter supplies the field of the generator, and a main exciter supplies the four fields of the actual driving motors. The separate field of the control exciter is supplied from the electronic control unit and, by governing the generator output voltage, it controls the speed of the driving motors moving the telescope. Shunt field regulators under automatic control carry out the field



The 250 ft. diameter reflector is supported on two trunnion roller bearings. Each is designed to carry a maximum radial load of 500 tons.

weakening control at high speeds. The normal operating speed of the motors is between 10 and 240 r.p.m. Interlock circuits prevent rotation of the telescope beyond fixed limits.

The telescope is designed to rotate through 420 deg. in the horizontal plane. A special cable-turning device avoids the use of slip rings, since these have an adverse effect on the various radio measurement cables and devices. The electrical installation work was carried out by F. H. Wheeler and Company, Limited. Numerous multi-core cables run between the control room and the annular laboratory beneath the main structure. These cables (having about 150 cores) are taken through another turning device, again without the use of slip rings. A sub-station, located over the central pivot, houses the electrical equipment. The sub-station rotates with the telescope.

Structural steelwork receives a coat of red lead priming followed by one undercoat and one final coat of synthetic hard gloss paint. The final colour is light battleship grey. Thomas Cotton, Limited, carried out the painting. The bowl membrane steelwork is to be cleaned by rotary wire brushes and, after the application of a corrosion inhibiting primer and undercoat, finished with a synthetic flat white paint. In this way it is hoped to minimise specular reflection and the absorption of heat.

Two passenger lifts, one in each of the main towers, number among the hoisting equipment supplied by Herbert Morris, Limited. Each lift is able to carry three people and serves three landing entrances. The total travel is 130 ft. The speed is 120 ft. per minute.

Large pneumatic tyres on commercial-vehicle wheels damp out vibrations set up by high wind. Inverted transport bogies exert a restraining influence on a steel rim—the "bicycle wheel"—behind the bowl. The tyres, give smooth and resilient rolling characteristics and a high frictional grip on the surface of the track, Restraint is by an automatic hydraulic braking system. The equipment, supplied by Automotive Products Company, Limited, has a centralised power pack with a piston type accumulator. Micro valves, operated electromagnetically, provide a means of interlocking the hydraulic circuit with the telescope drive controls.

A building some 200 yards from the centre of the telescope contains the control desk and computer mechanism. A large window directed towards the telescope allows the controller to see the whole of the telescope while he sits in his chair. Floodlight will illuminate the telescope at night. The control desk and computer system, which is governed by a sidereal clock, was developed and made by Dunford and Elliott, Limited. Useful consultations took place with the Naval Gunnery Research Establishment.

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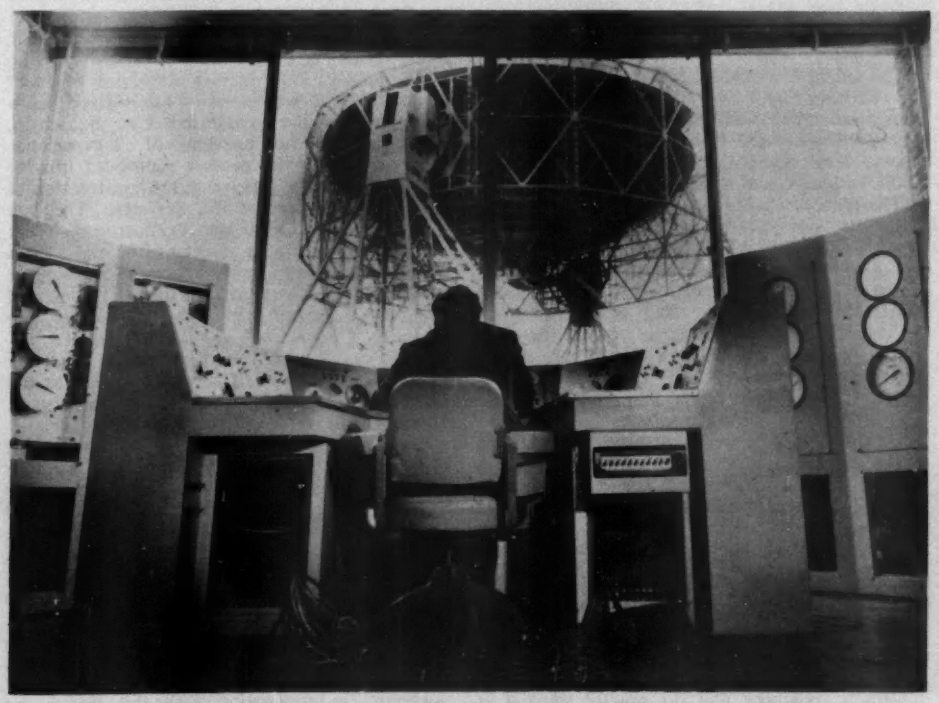

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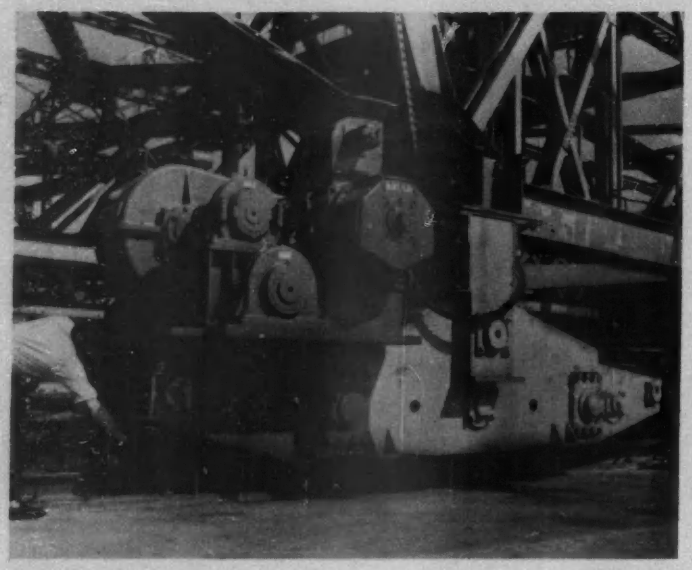


There are four driving bogies such as this. Owing to the very low speeds at which the motors normally run, forced ventilation is necessary. The total overall reduction from motor to track is 185/1.

but most of the rails are 42 ft. 1⅛ in. or 46 ft. 6⅛ in. long.

The inner rail on each circle is mounted on mild steel packing pieces ⅜ in. thick. The packing pieces lie the length of the baseplate but only extend the width of the rail flange, that is 5¼ in. Standard rail clips are used on the outside flanges of the twin rails, but the inner flanges are held by a specially made double clip. (The rail flanges stand 1½ in. apart at this position.) To allow for any settling of the track on the concrete formation, the countersunk bolts securing the mild steel clips to the baseplate are made 1 in. longer than normal. Thus additional packings can if necessary be put between the rails and the baseplate. To set the track to the fine limits required, cast iron wedges were used—six per baseplate. The wedges were supplied 3 in. wide, 6 in. long, tapering from 1⅞ in. to 1⅛ in.

The main structure of the telescope was erected by Cozens and Sutcliffe Limited under the supervision of the United Steel Structural Company, Limited. Most of the work was done with two 15 ton Scotch derricks. They were mounted on gabbard towers 120 ft. high equipped with railway bogies. Movement in two directions was possible by jacking up the bogies and turning them through 90 deg. From time to time crawler and pneumatic-tyred mobile cranes with capacities up to 15 tons and jib lengths of 90 ft. supplemented the main cranes. It was decided that the bowl would be supported during erection on 12 towers built up in tubular scaffolding structure.

In the fabrication shops, before work on site started, a large number of templates had to be produced. Very careful setting out was required to establish the shape of the radial trusses in the bowl, because their top chord had to conform to the correct parabolic shape. Actual fabrication of the steelwork started in the shops during May, 1954. The main difficulty was that most of the structures were so large that they could not be assembled in the shops; it was necessary to rely almost entirely on the accuracy of the individual components. The main radial girders had to be dispatched piecemeal and assembled on site. Care was called for in the bending of the 2,200 angle-iron purlins for the interior surface of the bowl. Each one had to be correctly curved in two planes.

The most important piece of shop assembling was that of the trunnions in the girder that carries the bowl driving rack. The assembly had to be accurate when it was lifted 165 ft. to its position at the top of the towers.

Erection started in August, 1954. Construction of the diametrical girder on temporary supports was begun—working out from the centre pivot. At each end of the finished girder, chord girders were put in place; under these the rail bogies were fixed, as they came to the site. Erection and bracing of the towers followed.

The bogies were assembled in three sections on their tracks. There are four driving bogies and eight wind carriages—the former weighing 16 tons, the latter 13½ tons. Each of the driving bogies has an individual driving motor unit that drives four monorail track wheels. Spur idler gears couple each track wheel. To accommodate the radius of the track the spur gears are cut with a slight taper on the teeth. Four wind carriages travel the outer track, the remaining eight bogies move on the inner track.

The wheels have cast iron centres with forged steel tyres shrunk on. Each tyre is tapered. Each wheel of the bogies is mounted on two parallel roller bearings and one ball location bearing. The bearings were supplied by the Hoffmann Manufacturing Company, Limited. This firm also supplied the bearing for the centre pivot, made by the Davy and United Engineering Company, Limited. Comprising two castings, weighing jointly about 13 tons, the pivot serves to locate the revolving structure. It has a double-row roller journal bearing with a bore of 30 in., outside diameter of 42 in. and a width of 7¾ in. While this bearing controls the whole structure sideways, taking the wind load, a single ball thrust bearing carries a portion of the weight.

In October, 1955, erection of the scaffolding started. A high tower of tubular scaffolding falsework—Mills Scaffold Company, Limited, were the contractors—was built over the centre pivot. On top of the tower the steel spider forming the centre of the bowl was erected. By this time the trunnion bearings had been fitted on the towers enabling the centre of the bowl to be accurately aligned between them. The trunnions, rack girders, and the first portion of the bowl circumferential trusses were erected on more falsework at either tower. It was then possible to erect and adjust the first four radial girders connecting the two trunnion assemblies.

It was proved that the whole sub-structure was accurate and little difficulty was experienced in getting the correct setting for the critical starting point for the bowl steelwork. Work then began building out fan-wise on both sides of the bowl. Each crane worked independently and each panel point on the circumference of the bowl was supported on tubular falsework. The steelwork was finally closed on the outer edge of the bowl on September 12, 1956. It was unnecessary to adjust the length of any of the closing members.

One of the main features of the telescope is the mild steel skin with which the whole of the inside of the reflecting bowl is lined. Welding by the metallic arc process was adopted and the membrane is made up from 14 gauge steel plates, 3 ft. square. The manufacture and fixing *in situ* was carried out by Orthostyle Limited. Over 7,000 plates were used.

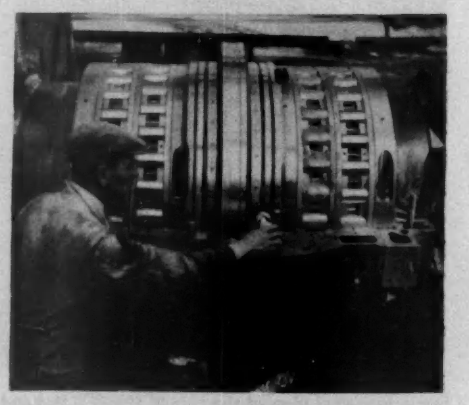
Expansion of the bowl is taken care of by the large thrust races in the main bearings. Hydraulic jacks give slight adjustment to the shape of the bowl. The tolerance for the position of the plates is ± ¼ in. In practice the framework makes it rather more.

The two trunnion roller bearings that support the reflector of the telescope were designed and manufactured by the Cooper Roller Bearings Company, Limited. The roller bearings, while not the largest made by the company, have the greatest load/diameter ratio of any made up to the present time. Each bearing can carry a radial load of 500 tons and an axial or thrust load in either direction of 125 tons. The bearings have a bore of 30 in. Each has four rows of rollers 2⅜ in. in diameter by 3¾ in. long, to carry the radial load. The inner and outer races are in two halves to the circle.

Two distinct sets of transmission gears have been installed, one to effect the movement of the bowl—the elevation gears; the others to rotate the structure on the steel tracks—the azimuth gears. Both sets were manufactured and installed by Alfred Wiseman and Company, Limited. One azimuth transmission set is mounted on each of the four powered bogies. The set consists of a standard double-reduction spur-gear unit followed by larger gears. The total overall reduction from motor to track is 185/1. Two sets of gears in tandem rotate the telescope bowl. Each gives an overall reduction of about 21,500/1.

Electrical power for the telescope is supplied by a Brush/Mirrlees Diesel generating set at 400/440 volts, 3 phase, 50 c.p.s. The Brush Electrical Engineering Company, Limited, were responsible for the manufacture, supply and erection of all the machines, control gear and reduction gear equipment that move the telescope. Also the company supplied the electronic equipment that converts the requirements of the telescope controller into movement of the driving motors. The control equipment can be considered as two identical sets. One drives the telescope in azimuth, the other drives it in elevation. Each movement is actuated by means of four variable-speed direct-current motors. A speed range of 10 to 1,000 r.p.m. is got by Ward-Leonard control. By weakening the motor field, variation between 1,000 and 1,500 r.p.m. is possible.

The four motors of each drive are connected electrically in series. Since they usually rotate at very low speeds, forced cooling is necessary. Power is supplied from a 175 kW direct-current generator driven by a slip ring type of induction motor. Two exciters operate in conjunction with the motor generator set. A control exciter supplies the field of the generator, and a main exciter supplies the four fields of the actual driving motors. The separate field of the control exciter is supplied from the electronic control unit and, by governing the generator output voltage, it controls the speed of the driving motors moving the telescope. Shunt field regulators under automatic control carry out the field



The 250 ft. diameter reflector is supported on two trunnion roller bearings. Each is designed to carry a maximum radial load of 500 tons.

weakening control at high speeds. The normal operating speed of the motors is between 10 and 240 r.p.m. Interlock circuits prevent rotation of the telescope beyond fixed limits.

The telescope is designed to rotate through 420 deg. in the horizontal plane. A special cable-turning device avoids the use of slip rings, since these have an adverse effect on the various radio measurement cables and devices. The electrical installation work was carried out by F. H. Wheeler and Company, Limited. Numerous multi-core cables run between the control room and the annular laboratory beneath the main structure. These cables (having about 150 cores) are taken through another turning device, again without the use of slip rings. A sub-station, located over the central pivot, houses the electrical equipment. The sub-station rotates with the telescope.

Structural steelwork receives a coat of red lead priming followed by one undercoat and one final coat of synthetic hard gloss paint. The final colour is light battleship grey. Thomas Cotton, Limited, carried out the painting. The bowl membrane steelwork is to be cleaned by rotary wire brushes and, after the application of a corrosion inhibiting primer and undercoat, finished with a synthetic flat white paint. In this way it is hoped to minimise specular reflection and the absorption of heat.

Two passenger lifts, one in each of the main towers, number among the hoisting equipment supplied by Herbert Morris, Limited. Each lift is able to carry three people and serves three landing entrances. The total travel is 130 ft. The speed is 120 ft. per minute.

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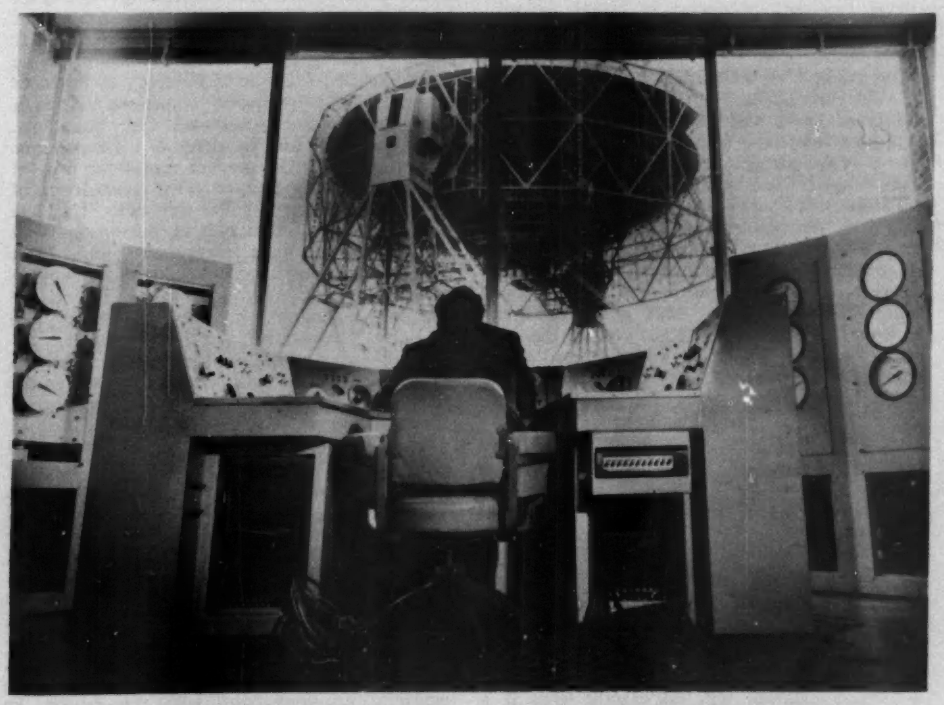

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AUTOMATION BRINGS CHANGE

People who present papers at conferences fall into two categories: those who chose their own titles and those who don't. Miss J. Woodward was one of the unlucky ones. However it would be unfortunate if the title "Control and communication—a management concept of cybernetics" prevented anyone reading her paper. It tells in a clear way how automation affects the running of a firm.

The paper is based on a research project that surveyed 203 firms in East London and Essex. It was read at the annual conference of the Institution of Production Engineers. Basically the firms studied can be grouped under three main headings—unique article and small batch production; large batch and mass production; process production. Careful comparison between the groups gave pointers to the effects of automation.

A limited amount of information about attitudes and behaviour was got during the survey. It suggested that technical demands influenced not only organisational structure, but also the general atmosphere and the quality of human relations. Pressure on people at all levels of the industrial hierarchy appears to increase as technology advances; until it reaches its peak in mass-production of the assembly line type. Then it decreases rapidly. This relaxation, together with the breaking down of the labour force into very much smaller groups and the decreasing emphasis in the process concern on labour economy—because of the comparatively low labour costs—makes industrial relations very much easier all round. This implies that automation and other forms of advanced technology, while they will give rise to the human and social problems inevitably associated with change, may in the long run solve many of our current industrial relations problems.

Speaking of the change that can be expected in the type of man who becomes a manager, Miss Woodward remarks "In the first place, it is doubtful whether in the industry of the future it will be possible to make sound administrative decisions except on a basis of technical competence. In the past we have tended to assume not only that there are principles of management proper to every type of production, but also that an able administrator can operate successfully in a number of different spheres and that administrative skill can be dissociated from technical competence. Many of the high level industrial appointments made in this country since the end of the war, particularly in the nationalised industries, have been based on this assumption. If, however, as the evidence of this research tends to suggest, sound decisions about the objectives and operation of a technically advanced firm can only be made by those with a knowledge and appreciation of its technology, wide implications follow for the selection and training of managers. The aim must be to develop administrative skill upon a basis of technical knowledge."

It is interesting to speculate whether these new developments in technology will bring to senior positions in manufacturing a different kind of executive personality. There are indications that this may happen. The manager of tomorrow will be more analytical than instructive. He will be a functional rather than a personality leader. His authority will be of a different kind; he may have more leisure, for he is likely to be hard pressed only when things go wrong.

Discussing the attitudes of the people working in a process industry, Miss Woodward pointed out that the plant itself constitutes a framework of discipline and control. The demands on the operatives are imposed by the plant rather than by supervision. Most people resent this type of authority less than that exercised over them by other people. The research workers found that in process industry the relationship between superior and subordinate was more like that between the booking clerk of a travel agency and his client than between the foreman and the operator in mass production.

A stimulating opening to the conference was given by the Right Hon. The Earl of Halsbury. Early in his paper, "The administration of modern production," he took pains to show clearly what is meant by the phrase "intuitive management." He then went on to discuss the new facilities available to management—linear programming, the theory of queues, real-time management. He pointed out that many criticisms of analytical methods made by intuitive managers were due to lack of understanding. They tended to expect answers to questions that were not in the analyst's brief. A firm advocate of the analytical approach, he nevertheless emphasised "If anyone expects me to believe that the intuitively clever person will lose his place in society, I can only deny the soft impeachment."

How much is automation going to cost? Mr. F. T. Hunter in his paper "The cost of automation," could not give a detailed answer. "What does seem reasonably clear," he said, "is that, as a broad generalisation, these modern techniques are profitable. That is, doubtless, a glimpse of the obvious in that design and management skills would not be being devoted to the subject were it not so, but what does not seem anything like so clear is just how profitable they potentially are. There are rumours that some of the developments announced to the world in stentorian tones as miracles, from which gold will flow in ever-increasing streams, have proved to produce mere trickles, and the proponents prefer not to discuss the subject."

Two people willing to discuss the subject were Mr. D. Player and Mr. W. K. Temple. In their paper, "Machine tools of the future," they listed the savings that they claimed could be made by using automatically controlled machine tools. Costs would be saved by:—

(1) a machine that spends most of its life cutting instead of waiting for an operator to plan and prepare his next action;

(2) the time normally spent in checking and rechecking settings being eliminated;

(3) lessening of operator fatigue with consequent higher productivity;

(4) the elimination of jigs;

(5) the reduction of scrap to a negligible level;

(6) the saving of inspectors' time, which also allows faster work flow.

As an example of the time that could be saved, the authors quoted a magnesium jet-engine component that was machined in 6 hours—compared with the conventional time of 57 hours. The component had a total of 130 holes ranging from 7¼ in. diameter downwards.

The authors admit that the capital cost of such automatic machines is high. Apart from the portion wrapped up in the machine itself due to the more expensive mechanical details, higher inherent accuracies, more rigid construction, better control facilities and extensive interlocking, there is also the basic cost of the electronic control equipment. That can easily amount to between 30 and 50 per cent. of the ultimate selling price, which may itself be double that of a hand setting machine.

In the first part of their paper the authors outlined three basic methods of automatic control, namely co-ordinate positioning, profile generation by copying, and continuous numerical control. They pointed out that automatic control was likely to have revolutionary effects on work inspection: "Certainly the time is ripe for a revolution, for increasingly we are being faced with the absurd situation that a component is produced in two hours and then takes two days to check. In the first place, it is necessary to accept without question that a well-designed automatic machine will do exactly what it is told within its own inherent limits of accuracy . . . we put to you the revolutionary idea that the inspector should do 95 per cent. of his checking before the component is even started." Thus it is the programming and the associated punched cards or tape that should receive the inspector's main effort.

The impact of automation on the design of products received the attention of Mr. D. L. Johnston. In his paper "Product design for automated production," he urged that much greater use should be made of simplification, specialisation, and standardisation internationally, together with a modular approach to the subdivision of machines and structures. This economises in design effort as well as in cost of production and distribution. Mr. Johnston had something to say about the smaller company. "The function of the smaller industrial companies will be:—

(*a*) making individual adaptations and composite assemblies of the basic products, by fabrication and batch production, to fill the gap as standardised production reduces the flexibility of the big producers;

(*b*) specialised manufacture of relatively simple series of components, using automated plant;

(*c*) miscellaneous jobbing and sub-contract work;

(*d*) service industries, including specialised plant installation and maintenance."

Speaking of the changing national economy, Mr. Johnston thought it would increasingly resemble a box packed with a few large spheres, with the interstices filled by many smaller and more mobile spheres. The large spheres represent the big manufacturing units, the small spheres represent the small firm. Such a situation leaves plenty of scope for initiative and imagination.

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Obituary

MAJOR W. G. WILSON, C.M.G.

We have learned with regret of the death of Major Walter Gordon Wilson, which occurred at his home, near Winchester, on June 30.

Major Wilson, who was born on April 21, 1874, and educated first in the naval cadet training vessel Britannia and then at King's College, Cambridge, where he received first-class honours in mechanical science, will be chiefly remembered for the distinguished part he played in connection with the development of the original tanks used in the first World War at the Battles of the Somme. When war broke out in August, 1914, he was already an engineer of repute and was soon commissioned as a lieutenant in the Armoured Car Squadron. In this capacity, and by virtue of his experience as a member of the pioneer motor-car firm of Wilson-Pilcher, he assisted in the construction of armoured vehicles for the Services. The late spring of 1915 found him at Burton-on-Trent engaged in technical experiments and, from then onwards, he was associated with Sir William A. Tritton, of the firm of Tritton, Foster and Company, Lincoln, in joint endeavours to devise a "landship" for the War Office.

Early ideas, such as the Tritton and the Centipede (the latter at one time known as the Wilson, incidentally), gave way to the Mother. This machine was a vehicle of rhomboidal shape with an upwards-pointing end and tracks all round on each side, and is the tank of familiar memory. After secret, and successful, trials at Hatfield, the Government ordered 100 examples of the Mother vehicle, which became thereby the prototype of the Mark I tank. Two types of that tank were used on the Somme. Major Wilson was awarded £10,000 for his services and received the C.M.G. in 1917. He designed the Wilson-Pilcher car, the Armstrong Whitworth car and the Hollford lorry, and was the inventor of the Wilson self-changing gearbox. In connection with this device, he became the founder and a director of Self-Changing Gears, Limited, Coventry.

Weekly Survey

Cover Picture: *Before gas is used in a furnace gas plant, all moisture must be removed and this is done in a simple condensing coil. The illustration shows such a coil being fabricated.*

* * *

Constructors to the Fore

The news that British industry is once again moving forward in factory building comes as a surprise to those who have for several years now been unaware of any slack and often unable to meet the heavy demands industrial expansion has made upon them. Two large firms of specialised engineering constructors, Simon-Carves Limited and Woodall-Duckham, Limited, have been exceptionally busy during the year ending December 31 and have several years work on order. The chairman of Simon-Carves, Mr. R. B. Potter, reported an increase of rather more than 10 per cent. in turnover and a rise of 30 per cent. in the value of orders in hand at the end of the year compared with December, 1955. Profits at £1·63 million, were only about £30,000 higher implying a narrowing of margins fairly general in an industry where labour accounts for a high proportion of costs. As things stand now, the company's prosperity "should be assured for some years." Mr. Potter points out, however, that very high expenditure on nuclear energy and (to a lesser extent) on other new processes which are being developed, must continue.

Mr. T. C. Finlayson, chairman of Woodall-Duckham who specialise in the construction of gas works, and the provision of carbonising and by-product recovery plants for the steel and coal industries, reports increased turnover by £200,000 to £14 million, profits (before tax) by £45,000 to £1·09 million and their order book to £25 million, or two full years work.

Both companies have large overseas contracts. Woodall-Duckham are building plants to a total value of £5½ million in South Africa, and Simon-Carves have orders for £17 million worth of steel plant as their share of a complete steelworks at Durgapur, India. The record of these two companies' activities at home and abroad is impressive and clear evidence that heavy industry is far from the peak of its current field of development. In anything concerning fuel, power and steel, much remains to be done all over the world and these two companies are strongly placed to get their good share of the business.

* * *

Mists, Fogs and Gases

This is hardly the season for reports on research into the nefarious effects of smog. Yet three publications received last week discussed the many problems that remain. *Polygon*, the journal of the Battersea Polytechnic, contained an article on the work of the Fog Research Unit which is based at the college. Research into the effects of chemical additives on the stability (and other properties) of fogs is being carried out under contract from the Ministry of Supply by a team led by Dr. G. A. H. Elton of the Chemistry Department. A very large new fog chamber of 27,000 cub. ft. has been constructed at Woolwich Arsenal, with ancillary laboratories and services. Completed in March last year, the chamber has been in use for several months. The unit are currently co-operating with a number of other organisations, including the Metereological Office, Imperial College, London Airport, the Royal Air Force, St. Bartholomew's Hospital, and the Fuel Research Station (D.S.I.R.) in the analysis of the hundreds of test results obtained during the fog season.

The allied field of gases, vapours and dust in industry was the subject of a review in the July issue of the F.P.A. Journal published by the Fire Officers Committee, Fire Protection Association. The main purpose of the review was to analyse the principal causes of explosions and to indicate measures of prevention, control and suppression. The fact that dusts can form an explosive mixture, e.g., titanium dust, by combining with the nitrogen in the air, makes a strong case for prompt extraction.

Mists and fogs from factory processes was the main subject dealt with in the *Annual Report on Alkali, etc., Works* by the Chief Inspectors, 1956. The report concludes that "reliable and fundamental research on the whole matter of mist formation is needed." The growth of certain industries, such as gas, sulphuric acid and cement is making this need more urgent.

* * *

Tanker Surplus

The decision of the British Petroleum Tanker Company to lay up nine medium-sized ships of about 12,000 tons deadweight underlines the very rapid change which has occurred in the tanker market since the re-opening of the Suez Canal. Six months ago a serious and continuing shortage of tanker tonnage was feared and the major oil companies chartered extensively in order to supplement the carrying capacity of their own fleets. British Petroleum now find themselves with a small surplus of capacity and the vitual cessation of chartering by the large oil companies has resulted in a severe fall in freight rates. Last December the rate for crude oil from the Persian Gulf via the Cape was £19 per ton: the current rate via Suez is just over £2.

Factors contributing to the decline in demand for tonnage have been the warm weather and the fall in demand due to the high price of petrol in recent months. That B.P. consider the decline in demand to be only temporary is shown by the fact that the nine tankers are to be laid up at Falmouth in such a way that they can be brought back to service at short notice.

Taking a longer view, some misgivings have recently been voiced regarding the size of present tanker building programmes and, in the United States in particular there has been some slowing down in new orders. This view is not shared by British Petroleum which announced a further batch of orders at the end of June. These comprised 27 tankers totalling 1,150,000 tons deadweight, which raises to 2,300,000 tons deadweight the total tonnage on order for this company. It has been suggested that the reason for this large-scale building is that B.P. has, on the average, longer hauls than most of the other oil companies and may therefore wish to reduce its dependence on chartered tonnage. The independent tanker companies must, however, be carefully reviewing their forward commitments in view of the low level of freight rates.

* * *

Learning for Comfort

More and more of recent years, questions of air conditioning and refrigeration have been coming to the fore, until the installation of such equipment is now regarded as almost automatic in many of our larger ships and buildings. Consequently, the importance of the National College for Heating, Ventilating, Refrigeration and Fan Engineering has also grown within recent years. At present, the college is very hampered for space, as is the case with so many technical colleges to-day, and classes are held in the annexe building of the Borough Polytechnic, Borough-road, London, S.E.1. However, the best possible use has been made of the space available, as was demonstrated to visitors at the open day held recently at the College.

Students, who are mainly drawn from industry, have an opportunity to carry out experiments and tests on modern refrigerating, air conditioning and fan equipment, as well as having theoretical lectures given in the classrooms. A specialised library caters for their needs and is also available for use by industry generally. The library produces a regular bulletin which contains abstracts of articles that have appeared in the technical Press of many countries, and is circulated both in the College and to interested bodies.

The college conducts assessed diploma examinations and courses leading to membership of the Institution of Heating and Ventilating Engineers. It also has limited accommodation for some research on special projects. The theses produced by students form a very excellent source of reference for particular sections of the general subject.

* * *

Boom in Dutch Shipbuilding

The fact that Holland now has full employment is making itself felt in the shipyards. The Dutch had the third largest tonnage of shipping under construction at the end of 1953, but at the end of last year, although production increased, their share had falien to fifth. Sixteen per cent. of the whole labour force is in shipbuilding. The Rotterdam Drydock Company, one of the largest repair firms, employs 5,000 men, but could find work for another 1,500 or 2,000. The labour shortage is equally acute everywhere. Holland's 230 shipyards employed nearly 46,000 workers at the end of September—and 177 of these yards had over 9,000 vacancies between them.

The pressure of work is so great that the Dutch shipyards are fully booked right up to the end of 1961. The bulk of the orders are for tankers, including super tankers of 65,000 to 80,000 tons. One Rotterdam yard is organising the assembly-line construction of tankers of 32,000 tons. It plans to build nine for a start.

The activity in the Dutch shipyards is all the more remarkable in view of the serious war damage they sustained. The new plant installed as a matter of necessity is now paying dividends. The main complaint is that the physical capacity of the yards is too great for the available labour force. But with record launchings and tonnages under construction last year the Dutch have no time to worry about that.

* * *

Sweden Orders Caravelles

The announcement last week that the Scandinavian Airlines System has become the first foreign company to place a firm order for the French Caravelle twin-jet medium-range aircraft gives rise to some interesting speculation regarding the future of the pure jet as opposed to the turbo-prop aircraft in the medium-range field. Does this mark the beginning of the end of the supremacy of the turbo-prop aircraft for medium-range work? Earlier this year, in the Brancker memorial lecture "The Economics of Speed" the chairman of British European Airways foresaw that the turbo-prop would have a long and useful innings on short-haul routes and should also have a useful but probably shorter career on medium hauls owing to its lower operating costs.

The Caravelle, which can cruise at 475 to 510 m.p.h. over a maximum range of 2,200 miles with 64 passengers, is not yet in service but twelve have been ordered by Air France and the S.A.S. contract is for six to be delivered during the first half of 1959, with an option on a further 19 to be supplied between 1959 and 1963. In addition Sud Aviation, the manufacturers of the Caravelle, have undertaken an intensive campaign to interest American airlines and the aircraft went on a sales tour of North and South America

in May. At the end of the month an alteration of the programme (which involved a diversion to Los Angeles for inspection by Mr. Howard Hughes) gave rise to a report that Trans-World Airlines were about to place a contract. T.W.A. have, however, also expressed interest in the 14 Viscounts no longer required by Capital Airlines. The latter, since the cancellation of their order for Viscounts and Comets, have also been named as possible customers for the Caravelle. It is reported that plans have been drawn up for the aircraft to be built under licence in the United States by Republic Aviation if sufficient orders are received. Hughes Aviation Corporation are also said to have offered to produce the aircraft in the United States.

Until the Caravelle is in service it is impossible to rate its strength as a competitor on the world's medium-range routes. Success for this aircraft would not be entirely unwelcome to the British aircraft industry since it is powered by two Rolls-Royce Avon engines.

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The Changing Face of I.C.I.

A detailed account of the growth of Imperial Chemical Industries during the past 30 years was given by their chairman, Sir Alexander Fleck, in his annual report to shareholders. It makes a fascinating story of change. Take the company's labour force: on formation in 1926, the proportion of staff to payroll workers was 1 : 4·1; it is now 1 : 2·3 and the proportion of staff is still rising. In the past ten years, the hourly paid labour force has risen from 70,000 to 80,000, but the monthly paid staff has grown from 23,000 to 35,000. At the same time the volume of production—" as best we can measure it in view of the different kinds of products which the company makes "—has more than doubled.

Much of the advance of the past ten years has been secured by heavy investment in the fruits of the company's research activities, the objectives of which were summarised by Sir Alexander as " to acquire knowledge for or likely to be applicable to practical ends." In I.C.I., research falls naturally into two main categories, which overlap and support each other. They seek respectively to " improve the manufacture of existing products and to discover new ones." The company's capital programme cost £44 million in 1956, making a total of £267 million spent on new fixed assets since the end of 1945. Some £83 million remained unexpended on all existing sanctions of capital expenditure at the end of last year.

If overseas companies are included, the total needed to finance outstanding projects will take over £100 million. The extent of change is shown by the fact that of the £44 million of capital expenditure sanctioned in 1956, some 52 per cent. is being spent on 15 products which were either not on the selling range in 1945, or were then being produced only on the pilot scale.

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Expansion on Severn-side

Sir Alexander Fleck's report discussed above was followed by an announcement that I.C.I. were seeking permission from the Gloucester County Council to develop a site of 1,000 acres on the Severn in the Thornbury Rural District. If permission is granted, a plant will be put up for the manufacture of organic and inorganic chemicals, relying to a large extent on oil as the main raw material. The choice of Severn-side was chiefly influenced by the availability of good port facilities which would allow the use of tankers of 30,000 tons capacity to bring the oil direct from the oilfields and the refineries. Another important consideration is that most of I.C.I.'s existing plants for the manufacture of organic chemicals, including plastics and ammonia products such as heavy industrial nitrogen chemicals and fertilisers, lie in the North of England. A major part of the market, however, lies in the Midlands and South, and the site is favourably located for both road and rail distribution to the whole area.

The plant will be ultra-modern, and will " employ the latest developments in chemical technology." The company expect to spend about £100 million to develop the site between now and the mid-1970's. The capital investment per man will average between £15,000 and £20,000, substantially higher than the £12,000 quoted by Sir Alexander Fleck as " the total costs of construction of new production units . . . for each individual who will be concerned with their operation and administration." The total operating force is unlikely to exceed 5,000 people, a small number compared to the very large turnover anticipated.

The rate of expansion of I.C.I. thus gathers pace. Some £50 million will be spent on new plant this year, compared with £44 million last year. The reason for this Sir Alexander Fleck gave very simply: " There are great possibilities for the profitable development of the chemical business throughout the world; and we have available in this country many of the raw materials required, convenient of access, and of high quality."

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Small Cars in the United States

There are signs that the pattern of the United States market for cars is changing and is becoming more favourable to European types. The manufacturing costs of the American car industry have risen more in recent years than the average in industry, and for a time at least—until automatic techniques make possible a substantial reduction in labour costs all down the line, e.g., to steel and plastics production—United States-made cars are going to be relatively very expensive. Imports are therefore being stepped up to provide " cheap transport." The recent decision of General Motors Corporation to import and distribute through their dealer networks Vauxhall and Opel cars from their United Kingdom and West German subsidiaries is widely interpreted as proof that (*a*) small cars have come to stay in the American market and (*b*) that the leading United States manufacturers have no intention of producing small cars locally.

The decision of General Motors to distribute the Vauxhall and the Opel, which follows a similar decision of Ford to handle the products of their British company, will almost certainly lead to a major increase in British exports. In the first quarter of the year, 51,844 cars were imported, more than twice the number imported during the first quarter of 1956. This rate of increase is expected to be maintained and importers anticipate that nearly 250,000 foreign cars will be sold this year. Among the more popular makes is the Volkswagen, which accounted for 20,000 out of the first 50,000 European cars sold this year. The British Ford is probably a good second, while British Motor Corporation exported cars worth 40 million dols. in the first half of the year.

Prospects for the small car are thus brighter than at any time since the war. Apart from price, ease of parking and general manoeuvrability are factors rapidly increasing in importance. They will make of the United States by far the largest import market for cars in the world.

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Half a Year Onwards

The Treasury has now published its thoughts in the latest " Bulletin for Industry " on the state of the economy in the first half of this year. The picture is encouraging on the whole. Most of the main industries are raising their production. Coal output is 3 per cent. higher than a year ago and the drop in gas, gas coke and electricity output below 1956 has been due entirely to milder weather and does not indicate any industrial interruption of importance. Steel output increased by 4 per cent. in the first five months of the year and returns indicate that chemicals output is also rising.

So far as investment demand is concerned, which is the main immediate interest of the engineering industry, official sources indicate that from data received so far, investment by manufacturing industry in the first quarter of the year was one-tenth higher than in the same period of 1956. This increase was rather smaller than the average increase for this time of the year in recent years, but the lack of resilience owes a good deal to the slow recovery of motor vehicle production in the early months. There has now been a significant recovery in the output of this industry and the figures of the second quarter of the year may show a large acceleration in capital investment. The prospect for building activity is dealt with in other notes but the performance so far in 1957 suggests that mild weather enabled the plans approved and put in hand to be more quickly translated into site clearance and building work than is normal during the winter months. This shortening of the period of gestation between plans and work on site probably means that the fall in plans approved has had less effect on industrial output than might have been expected. Now that the prospect for factory building is improving again, it seems likely that building will have a buoyant effect on the level of industrial activity right through 1957 and well into 1958.

The export trade is expected to be buoyant for some time to come. World trading conditions are thought to be good although the rate of expansion in world trade may be a little slower than in 1956. In the first half of this year engineering exports were growing more slowly than in the same period of 1956, the main deceleration being in ships, aircraft and general machinery. On the other hand, exports of metals have continued to expand quickly.

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Fits and Starts

The opinion is widely held that the amount of new factory buildings started in 1954 and 1955 played an important part in generating inflation in 1955 and 1956. By the same token, the drop in factory building and in building plans approved by the Board of Trade has played a useful part recently in containing inflationary expansion. It has been said, indeed, in these notes, that the continuing low level of factory building (by recent standards) might help to generate an industrial recession in the late months of this year and in the spring of 1958. The latest returns show a marked recovery in industrial building plans.

The number of schemes approved for the second quarter of this year at 18·8 million square feet is slightly above the quarterly average for 1956 and 37 per cent. above the level of the first quarter of this year. It will take more than these industrial swallows to make a summer in 1958, for not all plans which are approved are finally carried through, but the trend of factory building usually follows the trend of approvals fairly closely. If this quarter's returns should be followed by buoyant figures for the third quarter of the year, there is little doubt that a vigorous impetus will have been added to industrial activity for next year.

Industrial expansion is now assured, short of an international crisis affecting sterling, for the rest of this year and most of the brakes which were put on industrial production by the credit squeeze have now been taken off. Unless there is a substantial increase in productivity in progress, we are back where we started. Wages and salaries have increased, consumer expenditure is rising and there will be a further outbreak of inflation unless the increased money income now being expended is offset by a corresponding increase in the production of goods.

TESTING THE RELIABILITY OF COMPLICATED MACHINES

Improved Mathematical Model for Prototype Trials

By G. Morris, PH.D., F.INST.P.*

The task of developing a complicated machine, whether it be an aeroplane or a chemical plant, involves the discovery of faults and their correction. As such development proceeds it becomes subject to diminishing returns and so far as reliability is concerned, it is desirable to know when development of the prototype ceases to be economic. Even in the drawing-board stage the minimum time between overhauls of the finished machine can be estimated and the problem is to discover whether this will be achieved in practice. In an article published in ENGINEERING *on November 25, 1955 (page 723), Dr. Morris showed how it is possible to ascertain the final reliability of a machine from observations of the occurrence of faults at a comparatively early stage of the development period. One of three possible courses can then be adopted: to abandon design entirely; to re-design the machine embodying what has been learned from the first one, and to proceed to further development; or thirdly, to accept the design despite its obvious limitations. In the first article an idealised picture of the way in which engineers develop a design was used. In the present article the less perfect methods of real engineering are recognised and applied. Dr. Morris has now increased his examples from three to nine, to all of which a very simple model applies. A very much simpler method of fitting the model to the trials data is described in detail.*

Introduction

In a previous article in this journal[1] it was shown that the rate of failure of any machine, and more particularly the changes in that rate which occur as a prototype machine is developed, can be represented to a high degree of fidelity by a simple mathematical model consisting of several families of faults, each family comprising n faults, each of an equal probability of occurrence p.

It was found, for the three machines examined, that two such families sufficed; one, a small number (n_1) of " primary " faults each of fairly large probability of occurrence p_1, and the other a large number (n_2) of " secondary " faults, each of small probability p_2. The " primary " faults are eliminated in the course of development, with increased reliability of the machine, but the elimination of a small number of secondary faults such as are noted during a development trial will have no significant effect on reliability.

It was shown in the paper referred to above that the qth *primary* fault would be expected to occur after a number of trials (T_q) given by:

$$T_q = \frac{1}{p_1} \sum_{r=0}^{r=q-1} \frac{1}{(n_1 - r)}. \quad . \quad (1)$$

During this period $T_q n_2 p_2$ secondary faults would also be expected to occur.

Very little can be done with these formulae analytically, except when n_1 is so large that $\frac{1}{2n_1}$ and higher reciprocal powers can be ignored, and the number of primary faults F_p follows an exponential leading to:

$$F = F_p + F_s = n_1(1 - e^{-p_1 T}) + T n_2 p_2. \quad (2)$$

It is shown in Appendix 1 that this is the same expression as would be obtained on the assumption that each family of faults follows a Poisson distribution, an assumption which forms the apparently intuitive basis of the current studies of the reliability of electronic devices.[3] (See Appendix 4.)

Although intractable analytically, equation (1) is fairly easily handled numerically, and a routine procedure for determining n_1, p_1 and $n_2 p_2$ from the data of a prototype trial was described in a letter to this journal.[4] It was found that equation (1) gave a good fit for the data of three prototype " machines " which had been examined at the time the first article was written.

The reliability model promises to have some practical use, since it shows that after a time all the primary faults will be eliminated, and that thereafter the machine will have a constant failure rate which development work, no matter how prolonged, will not change. If this final developed rate is unacceptably high, the only remedy is to re-design the machine. The principal value of the model lies in the fact that this final developed rate can be evaluated to better than the required degree of accuracy at quite an early stage in the trial, and some time before all the primary faults have been eliminated from the machine.

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A More Realistic Approach

The model which has been considered so far was based on two assumptions:

(1) that all the primary faults were of equal probability of occurrence (p_1), or were spread symmetrically about a mean value;

(2) that when a fault occurred, the trial was stopped until a modification could be made to the machine such that this fault would never occur again.

Assumption (1), although idealised, is necessary if any mathematical progress is to be made. Assumption (2) can never describe a real development trial, since in practice the machine is seldom run solely to determine its reliability. For example, its operating staff have to be kept busy or found other employment, also, unless the initial design was very poor, it will not be immediately apparent how the modification to eliminate a fault is best to be made. In practice, when the machine breaks down it will usually be repaired, a repair being defined here as the replacement of a broken or faulty part by a nominally identical spare part, the removal of a faulty piece of material on which the machine is working, or the adjustment of some part to bring it back to its original position. A repair will have no effect on the rate of failure of the machine; if no modifications were made, a graph of faults (F) against trials (T) would be a straight line, obscured to some extent by the statistical scatter of the points. If a successful modification is made, the slope of the graph will change abruptly and a new straight line can be drawn from the point on the graph at which the modification was made to the point where the next modification is made.

The occurrence of a final straight line portion of an F – T diagram does not mean, as was implied in the previous article, that development of the particular prototype is complete, but may merely show that the engineer in charge of the trial has made no useful modifications during this part of the trial.

Calculation of the Model Parameters

It will be shown later that the final developed rate of breakdown for the machine can still be found from the mathematical model. If a trial has repairs for the first $(a_1 - 1)$ failures, then a modification at the a_1th failure and a further $(a_2 - 1)$ repairs and so on, equation (1) is modified to be:

$$T_q = \frac{1}{p_1}\left(\frac{a_1}{n_1} + \frac{a_2}{n_1 - 1} + \frac{a_3}{n_1 - 2} + \frac{a_4}{n_1 - 3}, \text{ etc., to } \frac{a_q}{n_1 - q + 1}\right).$$

It might be thought that if a record of those faults at which modifications were made is available, the fitting of a best model could proceed by the method already described,[4] with the small change that the value of X does not change after every fault, but only after each modification.

In practice, this is not so, for three reasons: (1) that successful modifications may have been made not to primary causes of fault but, inadvertently, to secondary causes; (2) that despite the best endeavours of the engineer, the attempted modification may not significantly affect the frequency of the fault; and (3) that modifications do sometimes occur without being recorded in the trial log—an example is a change of operating procedure due to increased experience of the crew. Examples of this will be seen in Figs. 2, 3 and 4, where the large dots represent

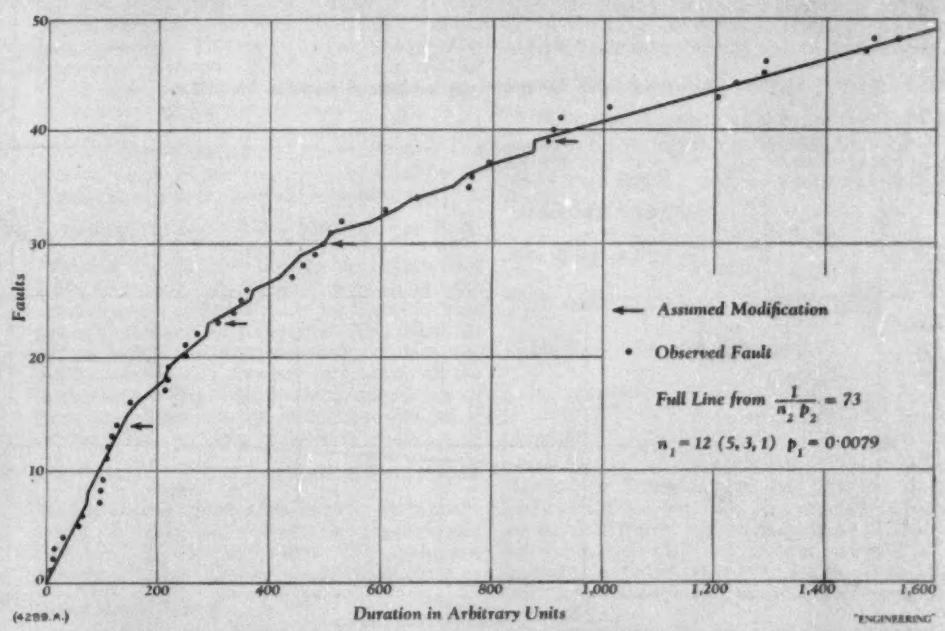

Fig. 1 Trial data for prototype machine 1, showing faults occurring over the test period. Curve is a revaluation of data for a machine referred to in a previous article.

(See Table III and also Table I, and Fig. 2 of article published in ENGINEERING, vol. 180, page 723, 1955.)

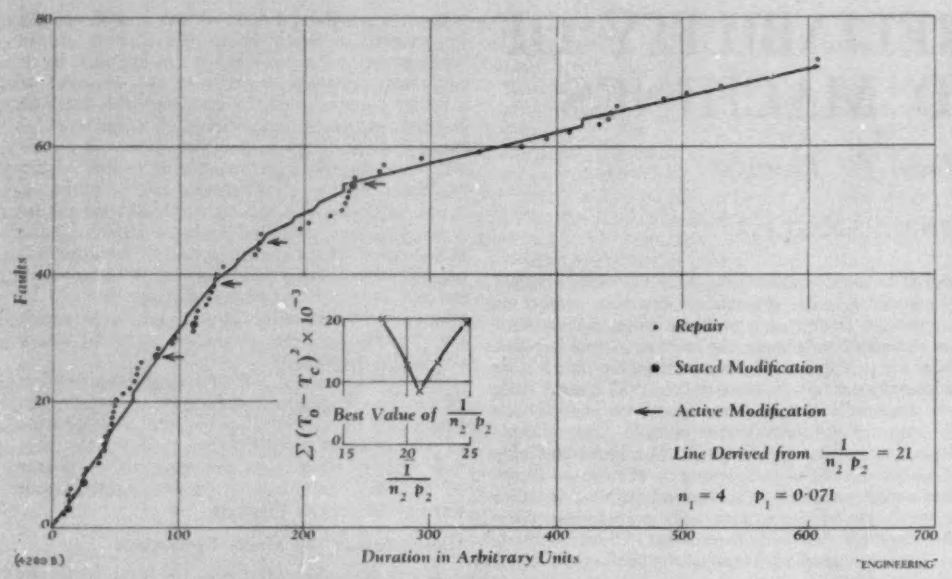

Fig. 2 Curve representing faults plotted against duration of trial for machine 3. By systematic treatment of results obtained in prototype trials, it is possible to determine the point at which such trials might profitably be discontinued.

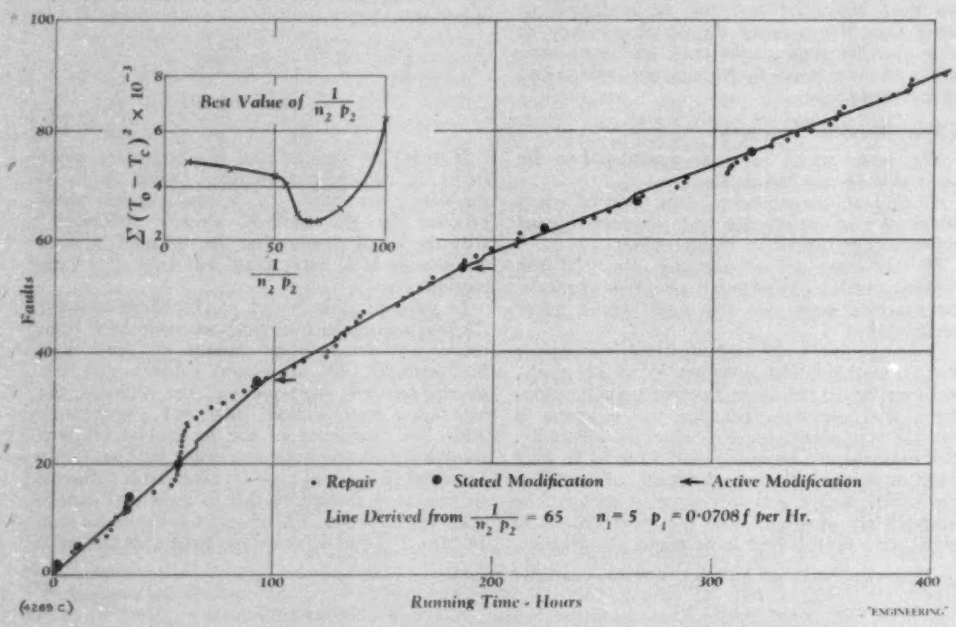
Faults
Running Time - Hours
Repair
Stated Modification
Active Modification
Line Derived from 1/(n2 p2) = 65 n1 = 5 p1 = 0·0708 f per Hr.
Best Value of 1/(n2 p2)
Σ (To − Tc)² × 10⁻³
(4269 C)
"ENGINEERING"

Fig. 3 Fault-time curve for prototype sublittoral seaweed harvester.

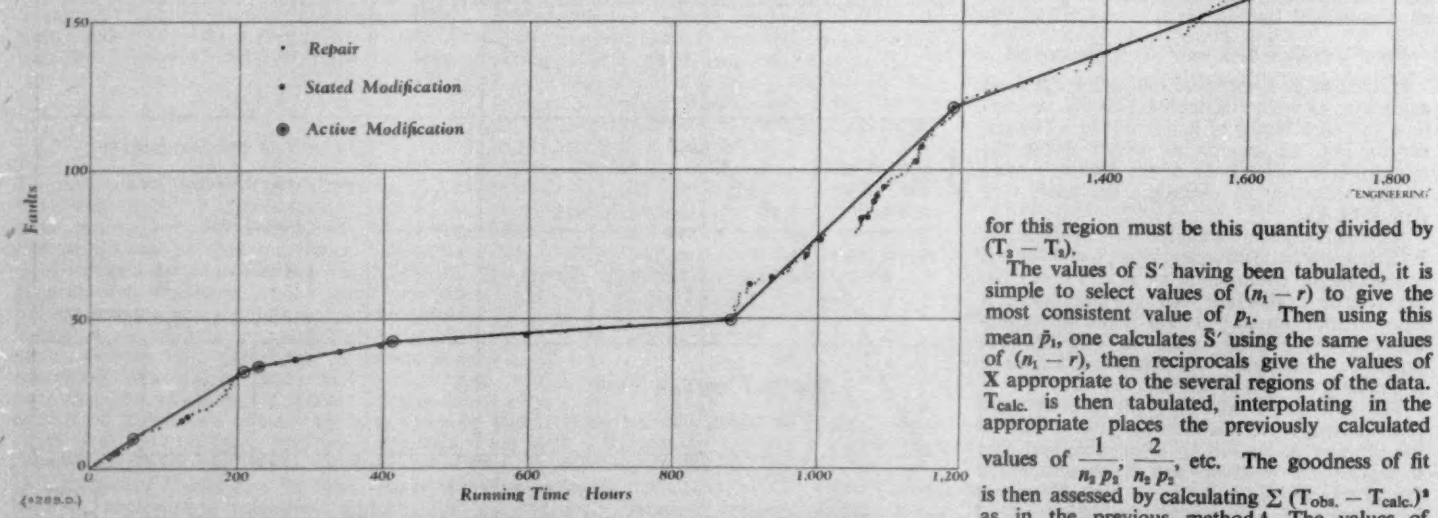

Fig. 4 Analysis of the reliability of the ignitron/rectifier system for the 340 MeV synchrotron at the University of Glasgow.

the faults which were followed by what were described as "modifications"; in each example not all of the "modifications" cited were effective in changing reliability.

The recommended procedure is to plot the faults/trials graph and to draw in with a straight edge those parts of the graph which can best be fitted by straight lines. If a record of modifications is provided, the turning points of the polygonal diagram so drawn ought to be some of the stated "modifications."

The formal system described previously[4] could then be applied, but this entails more labour than is necessary. A simpler method can be used. It is shown in Appendix 2 that the slopes S_r of the straight line portions which have been found on the graph should be approximately described by equations of the form

$$S_r = (n_1 - r)\, p_1 + n_2\, p_2$$

where, in the ideal case, r takes the values of the integers from 0 to n_1. In practice, all the values of r will rarely be found. This procedure does not give a unique value of $n_2\, p_2$, since the equation is obviously satisfied equally well by $(n_1 - (r-1))\, p_1 + (n_2 p_2 - p_1)$, etc.

In contradistinction, the previous method[4] can be shown to give a unique value of $n_2\, p_2$, since to give a best fit one has simultaneously to fit two unrelated sets of data—the occurrence of primary and secondary faults. The reason why the simple slope method described above does not give a unique value is that it implicitly ignores the dual nature of the experimental data.

A simple method which does give a unique solution is to assume a value of $n_2\, p_2$ and to cast out from the experimental data those faults having T values as nearly as possible corresponding to $\frac{1}{n_2\, p_2}$, $\frac{2}{n_2\, p_2}$, etc., to as many values as are needed. The slopes of the re-plotted data should be related by

$$S'_r = (n_1 - r)\, p_1$$

where, as before, the r values should be the integers from 0 to n_1. Data re-plotted after casting out sometimes reveal turning points which were not previously apparent. The slope values can be determined graphically or by some system such as least squares. In practice, re-plotting is not needed if the turning points have been selected from among the stated modifications. If the turning points are at F_1 T_1, F_2 T_2, etc., one knows that the number of secondary faults in, say, T_2 is $n_2 p_2 T_2$, so that the faults in the range T_2 to T_2 are $(F_2 - F_2 - n_2\, p_2\, (T_2 - T_2))$, and S'_2 for this region must be this quantity divided by $(T_2 - T_2)$.

The values of S' having been tabulated, it is simple to select values of $(n_1 - r)$ to give the most consistent value of p_1. Then using this mean $\bar{p}_1$, one calculates $\bar{S}'$ using the same values of $(n_1 - r)$, then reciprocals give the values of X appropriate to the several regions of the data. $T_{calc.}$ is then tabulated, interpolating in the appropriate places the previously calculated values of $\frac{1}{n_2\, p_2}$, $\frac{2}{n_2\, p_2}$, etc. The goodness of fit is then assessed by calculating $\Sigma\, (T_{obs.} - T_{calc.})^2$ as in the previous method.[4] The values of $\Sigma\, (T_{obs.} - T_{calc.})^2$ are plotted against the assumed value of $n_2\, p_2$, or more conveniently its reciprocal,

and that value of $n_2 p_2$ which gives the minimum value on this graph is selected as the "best" value. An example is given in Appendix 3, and Fig. 5 shows the result of applying the new procedure to some data already worked by the old procedure.[4] The agreement of calculated and observed values may be judged from Fig. 1.

The method is not very sensitive to the selected value of n_1, or of p_1, but is very sensitive to $n_2 p_2$. Since $\frac{1}{n_2 p_2}$ is the expected failure rate of the machine when development is complete, this is the parameter of the reliability model which the development engineer most urgently requires as accurately as possible.

It will be seen from Fig. 5 that not only does this suggested procedure give the same value of $\frac{1}{n_2 p_2}$ as is found by applying the earlier laborious method,[4] but it gives a much better fit to the experimental data as witnessed by the smaller value of $\Sigma\,(T_{obs.} - T_{calc.})^2$ despite the large contribution made by the experimental scatter of the data. If the region corresponding to $n_2 p_2 - p_1$, providing it is physically possible, is explored it will usually be found to correspond to a dip in the sum curve, but at a much higher sum, corresponding to a much worse fit than is obtained at the true value of $n_2 p_2$. The goodness of fit of the calculated values $T_{calc.}$ will be apparent on inspection of Figs. 1 to 4.

As a further argument in favour of rejecting the assumption of instant and invariable perfect modification,[1] it will be seen on comparing the legend of Fig. 1 with that of Fig. 2 of the original article[1] that the model obtained by the procedures of this article has a much smaller value of n_1 than the earlier model,* moreover the values of $\frac{1}{p_1}$ will be found to correspond better to the observed frequency of occurrence of the more frequently occurring faults, which must be assumed to be primaries.

While it is likely that the analysis of reliability will usually be made by the engineers running the trials of a prototype, the author has found that it makes little difference in the task of analysis if one is well acquainted with the detailed construction and performance of that prototype or has only a general idea of what the machine is for and no details at all of its construction.

Examples of the Use of the Model

In all, development trials of some nine "machines" have now been examined. Of these, three were complicated automatic feed mechanisms designed for a similar duty by three different designers; two were chemical plants; two were automatic analysis instruments, one based on a chemical, and one on a physical method; one was the ignitron-rectifier switch of a synchrotron; and one was a machine for harvesting seaweed.[5] In every case two families of faults sufficed to make a model, the behaviour of which was very close indeed to the reliability of the real mechanism (Figs. 1 to 4).

The seaweed harvester is an interesting example of the use of the reliability model. At the end of the reported trial, after 405 hours of working, the average failure rate was one breakdown in 6·4 hours, but the model indicates that the final rate of failure could have been reduced to about 66 hours per fault, a tenfold improvement in reliability, by the elimination of only two of the remaining causes of failure.

The analysis of the ignitron-rectifier switch of the University of Glasgow synchrotron shows a peculiar behaviour which the model can deal with satisfactorily; Fig. 4 shows the record and the fitted graph. Up to 882 hours running the curve is that normally to be expected for a prototype machine. Then the number of primary faults suddenly increased and the curve thereafter settled down to approximately the same final rate which, in both cases, may be interpreted as being due to the secondary faults only. It

* *Essentia non sunt multiplicanda praeter necessitatem.*

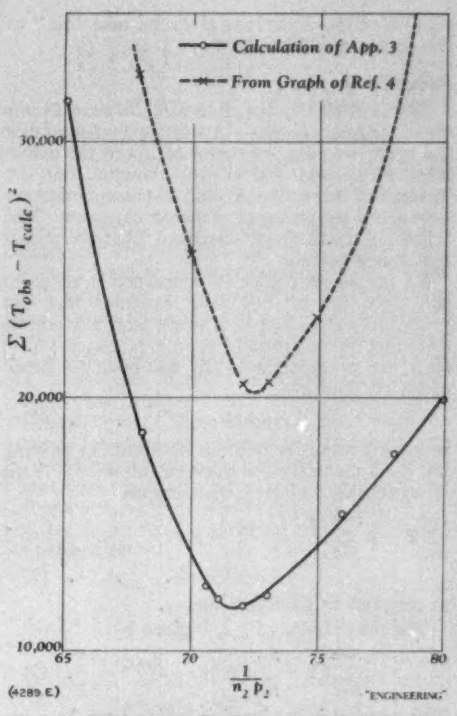

Fig. 5 Values of $\Sigma\,(T_{obs.} - T_{calc.})^2$ plotted against assumed values of $\frac{1}{n_2 p_2}$ for the first 40 values obtained from machine 1.

was concluded on theoretical grounds, and confirmed by inquiry, that at this point the load on this particular section of the machine was suddenly increased, so that parts which had a small liability to breakdown became, by reason of the greater stress on them, much more liable to breakdown, and in the language of this article were promoted from secondary to primary causes of failure. A similar change of reliability with increased load has been reported from elsewhere.

Another machine, after partial development, was taken by its makers to one factory of the purchaser, where development was continued until all the primary faults had been eliminated. It was then transferred to another factory belonging to the same firm. On arrival it was found that the rate of failure had increased, and was in fact equal to what had been recorded before the last successful modification. That is to say, during transport a new primary cause of failure had appeared. This was in due course satisfactorily "developed out" when the rate of failure returned to what calculation indicates to be the final rate for this machine.

A prototype gas analysis instrument was put into continuous service on a chemical plant and records taken of the frequency of breakdown. These records were analysed and gave $n_1 = 30$, $p_1 = 0{\cdot}00171$, and $\frac{1}{n_2 p_2} = 230$ days per fault. Although the machine had by no means been fully developed, seven more were built, the design being modified to allow for the experience gained in running the prototype. The reliability of the seven instruments varied considerably, but an average was obtained by treating all the instruments as one single machine, due allowance being made when any one instrument was out of service. The analysis yielded $n_1 = 40$, $p_1 = 0{\cdot}0112$ and $\frac{1}{n_2 p_2} = 30$, indicating that on the average each instrument had initially six primary causes of failure and a finally developed failure rate of 210 days per fault. The agreement between 230 and 210 days is very satisfactory.

Experimental Scatter

It can be shown by a statistical argument that the scatter of experimental results about the curves predicted by the model will necessarily be wide, and since this scatter can be derived wholly from the mean value it contains no new information (see Appendix 4).

Conclusion

The method suggested in this paper gives a mathematical model of the reliability of a prototype machine, which agrees more closely with the behaviour of that prototype than does the model calculated by the previous method, the assumptions made are more plausible, and the labour of fitting is considerably reduced. But the use of the model remains unchanged. By its application it is possible at an early stage in the trial to assess with adequate accuracy what the reliability of the machine will be when development is complete. This is one of many facts which have to be borne in mind in determining how long the trial should go on, and whether an early re-design is economic. It is believed that very large savings of money and, probably more important, of time could be made by its application.

Acknowledgment

The author wishes to express his gratitude to the following, who have given him data to analyse, Mr. D. Clayton, Mr. J. D. Fawcett, Mr. P. Jackson, Mr. G. H. Laycock and Dr. W. McFarlane, and to all those colleagues with whom he has had illuminating discussions on reliability models and their use.

APPENDICES

Appendix 1

The Equivalence of the Reliability Model and a Poisson Distribution.—It is shown in text-books of statistics[3] that the fraction of events, following a Poisson distribution, which has not occurred after a time t is $e^{-\frac{t}{\bar{t}}}$, where $\bar{t}$ is the mean time interval of the distribution. Expressing this in terms of number of trials made, the fraction is $e^{-\frac{T}{\bar{T}}}$. Since the probability of all the primary faults is assumed equal at p_1, then $\bar{T} = \frac{1}{p_1}$. Thus the number of faults F out of a total possible number n_1 which have occurred after T trials is

$$F = n_1 (1 - e^{-p_1 T})$$

which is the same expression as was derived by quite a different argument in Appendix 1 of the initial article.[1]

Appendix 2

A Formula Connecting the Slope of the Graph with the Model Parameters.—Assume that the model initially contains n_1 primary causes of failure, each of probability p_1, and that secondary causes produce a fault, every $\frac{1}{n_2 p_2}$ trials. If the first modification occurs after F_1 faults at T_1 trials, $T_1 n_2 p_2$ of the faults will be due to secondary causes, and $F_1 - T_1 n_2 p_2$ to primary causes. But the initial primary rate of failure will be $n_1 p_1$ faults/trial, so that

$$n_1 p_1 = \frac{F_1 - T_1 n_2 p_2}{T_1}$$

from which $n_1 p_1 + n_2 p_2 = \frac{F_1}{T_1}$.

Similarly, after r modifications

$$(n_1 - r)\, p_1 + n_2 p_2 = \frac{F_{r+1} - F_r}{T_{r+1} - T_r}.$$

Appendix 3

An Example of the Application of the Proposed Method of Computation.—So that a direct comparison can be made, this example is based on the data for the first 40 faults listed in Table I of the first article,[1]—which was analysed in a subsequent letter[4]—no information about the occasions on which modifications were made was available.

(*a*) *Preliminary Examination.*—The data were plotted and best straight lines drawn by eye. Turning points were apparent at Faults 14, 23, 30

and 39 (see Fig. 1), and the first two columns of Table I listed. From this the slopes $\left(S = \frac{\Delta F}{\Delta T}\right)$ were calculated; as shown, these were found to be well fitted by $n_2 p_2 = 0{\cdot}013$, giving $n_1 = 8$ and $p'_1 = 0{\cdot}0109$.

(*b*) *Detailed Calculation.*—Assume a value of $\frac{1}{n_2 p_2} = 68$. Then, secondary faults may be expected to arrive at 68, 136, 204, etc., trials. By T = 136, the first turning point, two secondary faults will have been expected, leaving 12 faults to be attributed to primary fault causes, with a slope due to primary faults only of $\frac{12}{136} = 0{\cdot}0897$. Similarly, by 302 faults, the second turning point, four secondary faults would be expected, leaving seven primary faults between 136 and 302 trials.

In this way columns 2, 3, 4 of Table II are obtained. Values of $(n_1 - r)$, etc. (column 5), are then selected, which will give nearly equal values of p_1 (column 6). The mean value of p_1 is then found. It may be found that several choices are possible, giving different values of $\bar{p}_1$. If an accurate value of p'_1 is needed, each should be tried and worked right through. That having the smallest sum of the squares of the deviations is the best fit. At the same time, Occam's razor calls for the smallest value of n_1 which will give a good fit. Inspection of the data will often give an indication which, of several values of p'_1, is to be preferred. Column 7 is now obtained by multiplying the values of column 5 by p'_1 and writing down the reciprocals.

The observed values of T at which faults occurred are then listed on a separate sheet (cf. Table III), and the columns of $T_{calc.}$ calculated under the heading of the assumed value of $n_2 p_2$. It is convenient to draw a line below the turning points. It is necessary simply to write down the multiples of the values of column 7, changing to the value appropriate to each range as the horizontal lines are passed, and to interpolate $n_2 p_2 T$ at the appropriate points. The calculated values should not be taken to more decimal places than the experimental values warrant. Finally, $(T_{obs.} - T_{calc.})$ is found, squared, listed and summed. That value of $n_2 p_2$ which gives the smallest sum of squares of the deviations gives the best "fit" to the experimental points.

TABLE I.—*Preliminary Examination for Machine 1: Turning Points Obtained from Curve (Fig. 1)*

Turning Points F	Turning Points T	ΔF	ΔT	$\frac{\Delta F}{\Delta T}$	$\frac{\Delta F}{\Delta T} - 0{\cdot}0130$	$(n_1 - r)$	p_1
14	136	14	136	0·1029	0·0899	8	0·0112
23	302	9	166	0·0542	0·0412	4	0·0103
30	496	7	194	0·0361	0·0231	2	0·0115
39	880	9	384	0·0235	0·0105	1	0·0105

$\bar{p} = 0{\cdot}0109$.

TABLE II.—*Detailed Calculation for Machine 1*

$\frac{T_r - T_{r-1}}{136}$

Turning points at: 136 trials for 14 faults
302 " " 23 " 166
496 " " 30 " 194
880 " " 39 " 384

(1) $\frac{1}{n_2 p_2}$	(2) $n_2 p_2 T$	(3) $F - n_2 p_2 T$ in range	(4) $\frac{F - n_2 p_2 T}{T}$	(5) Assumed $(n_1 - r)$	(6) p_1	(7) $\frac{1}{(n_1 - r)\ \bar{p}_1}$
(*a*): 68	2	12	0·0897	9	0·0100	10·8
	4	7	0·0422	4	0·0106	24·3
	7	4	0·0206	2	0·0103	48·6
	12	4	0·0104	1	0·0104	97·1
					$\bar{p}_1 = 0{\cdot}0103$	
(*b*): 80	1	13	0·0956	9	0·0106	10·6
	3	7	0·0422	4	0·0105	23·8
	6	4	0·0206	2	0·0103	47·6
	11	4	0·0104	1	0·0104	95·2
					$\bar{p}_1 = 0{\cdot}0105$	
(*c*): 73	1	13	0·0956	12	0·0079	10·6
	4	6	0·0361	5	0·0072	25·3
	6	5	0·0258	3	0·0086	42·2
	12	3	0·0078	1	0·0078	126·6
					$\bar{p}_1 = 0{\cdot}0079$	

Appendix 4

The Distribution of Intervals Between Faults about the Mean Value.—In practice it is found that the observed data are scattered about the calculated mean line and it was thought that the measure of this scatter might yield useful information about the progress of the development. The following elementary statistical analysis shows that this is not so.

So far as reliability is concerned a machine can only fail or not fail. Suppose that the probability of failing in a single trial is p (corresponding to the symbols, $n_1 p_1$, $n_2 p_2$, etc. in ref. 1) then the probability of its surviving to break at the tth trial is:

$$P = p\,(1-p)^{t-1} \quad . \quad . \quad (1)$$

where t is whatever unit has been used in plotting the F—T curve for the machine (cf. ref. 1). This is, of course, a discrete distribution.

$$\sum_{t=1}^{t=\infty} P = p \sum_{t=1}^{t=\infty} (1-p)^{t-1} = p\left\{\frac{1}{(1-(1-p))}\right\} = 1 \quad . \quad . \quad . \quad (2)$$

as required by statistical theory.

The mean value of t, $\bar{t}$, is given by

$$\bar{t} = \sum_{t=1}^{t=\infty} t\,P = \sum_{t=1}^{t=\infty} t\,p\,(1-p)^{t-1} = \frac{1}{p}. \quad (3)$$

This relation is the implicit basis of ref. 1.

The standard deviation of t is given by

$$\sigma^2 = \sum_{t=1}^{t=\infty} (t-\bar{t})^2\,P = \sum_{t=1}^{t=\infty} t^2\,P - \bar{t}^2. \quad (4a)$$

But

$$\sum_{t=1}^{t=\infty} t^2\,P = \sum_{t=1}^{t=\infty} t^2\,p\,(1-p)^{t-1} = \frac{2-p}{p^2}. \quad (4b)$$

Therefore, since $\bar{t}^2 = \frac{1}{p^2}$ $\quad \sigma^2 = \frac{1-p}{p^2}$.

I am indebted to Dr. S. Paterson for suggesting the method of summing equations 3 and 4 by successive differentiation of equation 2.

Since the distribution with which we are dealing is far from Normal, most engineers will have but little use for σ, but useful information can be derived from the distribution of the values of t about the mean value of $\bar{t}$.

A fraction $\frac{1}{M}$ of the values of t will lie in the range from 1 to and including t_1, where t_1 is given by

$$\frac{1}{M} = \sum_{t=1}^{t=t_1} P = \sum_{t=1}^{t=t_1} p\,(1-p)^{t-1} = 1 - (1-p)^{t_1}.$$

Taking logarithms

$$t_1 = \frac{\log\left(1 - \frac{1}{M}\right)}{\log\,(1-p)}. \quad . \quad (5)$$

When several families of faults are simultaneously acting on a machine the evaluation of t is not easy, but when only a single family is present, these formulae can be tested. An example of such data is found in the values quoted in Table I of my first article from the 40th fault. Here what work was done on the prototype had so little effect on its reliability that the data can be considered as for an unchanged "population." The difference between the values in the second column of the table corresponding to successive breakdowns were taken as the values of t and the standard deviation calculated. The value was 68·8, equation (4b) gives 72·5.

The distribution of t was also compared with equation 5, as follows:

t	Number of Values between 1 and t inclusive: Observed	Calculated from Equation 5
5	5	3·2
10	7	5·6
15	10	8·0
25	13	12·5
50	22	21·6
73 = $\bar{t}$	26	27·3
100	37	32·2
150	37	37·6
200	39	40·3
250	42	41·7

The mean value ($\bar{t}$) is 73.

The agreement, in so small a sample as 43 values, is very satisfactory, but the table illus-

TABLE III.—CALCULATION OF THE FIT TO THE RESULTS OF TRIAL WITH MACHINE 1—FIRST 40 VALUES ONLY

F	$T_{obs.}$	Assume $\frac{1}{n_2 p_2} = 68$: $T_{calc.}$	$T_{o.} - T_{c.}$	Assume $\frac{1}{n_2 p_2} = 80$: $T_{calc.}$	$T_{o.} - T_{c.}$	Assume $\frac{1}{n_2 p_2} = 73$: $T_{calc.}$	$T_{o.} - T_{c.}$
1	8	11	− 3	11	− 3	11	− 3
2	12	22	−10	21	− 9	21	− 9
3	13	32	−19	32	−19	32	−19
4	30	43	−13	42	−12	42	−12
5	58	54	4	53	5	53	5
6	64	65	− 1	64	0	64	0
7	95	68	27	74	21	73	22
8	97	76	21	80	17	74	23
9	100	86	14	85	15	85	15
10	101	97	4	95	6	95	6
11	107	108	− 1	106	1	106	1
12	110	119	− 9	117	− 7	117	− 7
13	117	130	−13	127	−10	127	−10
14	125	136	−11	138	−13	138	−13
15	144	154	−10	160	−16	146	− 2
16	148	178	−30	162	−14	163	−15
17	213	203	10	185	28	188	25
18	218	204	14	209	9	214	4
19	220	227	− 7	232	−12	219	1
20	247	251	− 4	240	7	239	8
21	248	272	−24	257	− 9	264	−16
22	271	275	− 4	281	−10	290	−19
23	308	300	8	304	4	292	16
24	334	340	− 6	320	14	332	2
25	351	348	3	352	− 1	365	−14
26	359	397	−38	400	−41	374	−15
27	441	408	33	400	41	416	25
28	461	446	15	447	14	438	23
29	480	476	4	480	0	458	22
30	496	494	2	495	1	501	− 5
31	510	544	−34	560	−50	511	− 1
32	528	591	−63	590	−62	584	−56
33	607	612	− 5	640	−33	627	−20
34	664	680	−16	685	−21	657	7
35	757	688	69	720	37	730	27
36	761	748	13	780	−19	754	7
37	794	785	9	800	− 6	803	− 9
38	—	816	—	877	—	876	—
39	897	883	14	880	17	880	17
40	911	884	27	960	−49	949	−38
$\Sigma (T_{o.} - T_{c.})^2$			18,592		19,723		12,287

trates that a wide scatter about the mean is always to be expected. Since this scatter can be calculated from the mean interval between breakdowns, it contains no additional information.

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SCIENTIFIC RESEARCH IN AUSTRALIA

The latest annual report* of the Commonwealth Scientific and Industrial Research Organisation states that the expenditure incurred during 1955-56 from all the funds at the disposal of the Organisation amounted to more than £6¼ million, of which the major portion was derived from the Commonwealth Treasury. This sum is 15 per cent. greater than the previous year's total expenditure.

The scope of research activity and the specific subjects under investigation are much the same as those covered by the 7th Annual Report,† but a minor reorganisation of the sectional laboratories has led to the establishment of a new Engineering Section, engaged, principally, in the fields of applied thermodynamics, utilisation of solar energy and the study of electronic control systems associated with such work. The Section has developed from the former Central Experimental Workshop which, for some years past, has undertaken the design and manufacture of special equipment for other research groups within the Organisation. This work is to be continued on a larger scale and extended to the investigation of air-conditioning and refrigeration problems, in the first place with special reference to installations of controlled temperature, humidity, and other climatic agencies for use in biological and general physical research; but eventually, no doubt, having wider and industrial applications.

Among the developments recently completed is a standard laboratory air-conditioner fitted with proportional control to its heating, cooling and humidifying operations, affording constant temperature within ± 1 deg. F. by means of a by-pass injection refrigeration system which, in conjunction with dry-expansion cooling coils, enables the evaporator to be maintained at substantially constant temperature, irrespective of load, without recourse to the complications, inconvenience and thermodynamic inefficiency of brine circulation. Relative humidity can be maintained constant within 1·5 per cent. by means of steam supplied by an automatic 3-phase electrode humidifier.

Apparatus developed for studies of dehydration of meat includes a weigh balance, with flexure pivot suspensory elements, accurate to better than 1 part in 10,000. In the field of solar heating, the Section has installed a number of experimental flat-plate water heaters at CSIRO establishments from which reliable data on radiation absorption are being regularly obtained. One of the trial heaters actually provides a hot-water supply for domestic use in the staff living quarters. It is hoped to encourage manufacturers to produce solar heaters on a commercial basis.

One other notable item in the Report concerns the large radio telescope which the Organisation proposes to build near Sydney. A contract has been let for a design study, to be undertaken by Freeman, Fox and Partners, the London consulting engineers, while a survey is in progress to determine a suitable site for the erection of the telescope in the neighbourhood of Sydney.

* Eighth Annual Report of C.S.I.R.O. for the year 1955-56. Commonwealth Government Printer, Canberra. (10s. 6d.)

† ENGINEERING, December 28, 1956, page 813.

STRESS-STRAIN CHARACTERISTICS OF A GRANULAR MATERIAL

By A. W. T. Daniel, M.A., PH.D., A.M.I.C.E.

For the solution of stress problems in soil mechanics, several methods are in general use, the most familiar being the developments of the classic Rankine-Coulomb theories, the Boussinesq equations, and such special methods as Janssen's for silos. In these methods the soil is assumed to possess properties which often differ considerably from those found in practice; but a greater anomaly lies in the fact that different assumptions are made in the different methods, even when the same soil is under consideration. In an attempt to find the stress-strain laws of a soil, which might form the common basis for all methods, the following work was performed. It has so far been confined to dry sand, of which two types were tested.

SYMBOLS

K_r = ratio $\dfrac{\text{horizontal pressure}}{\text{vertical pressure}}$ (Rankine)
p_y lb. per sq. in. = stress in the y direction, etc.
p_h lb. per sq. in. = stress in the horizontal direction when $p_x = p_z = p_h$
ϕ = angle of friction of sand or grain
ϵ_{yy} = compressive strain in direction y due to p_y
ϵ_{yx} = expansive strain in direction y due to p_x etc.
ϵ_y = total strain in direction y due to combined system of stresses
ϵ_h = expansive lateral strain when $p_x = p_z = p_h$
ϵ = $\epsilon_{xy} - \epsilon_h = \epsilon_h - \epsilon_{zy}$
α = $\dfrac{p_h}{p_y}$ in rigid cylinder case
C, D, E, b, k, m_0, n = constants found experimentally or otherwise
e = the exponential function

An apparatus was designed in which the behaviour of the sand was studied when subjected to a three-dimensional system of stress; while the stresses in the x and z directions were maintained constant at different values, the stress in the y direction was varied. The normal tri-axial apparatus was used, but with the sample contained in a reactangular cell so designed that the sides could move under the influence of the stresses. A steel framework was constructed so that, by means of interchangeable weights, various combinations of values of p_x and p_z could be used. By means of dial gauges the vertical and lateral strains were measured. The apparatus is shown in Figs. 1 and 2.

A series of curves was obtained which satisfied

$$p_y = \frac{(1+\sin\phi)}{(1-\sin\phi)}\sqrt{p_x\,p_z}\,(1 - b\,e^{-k\epsilon_y p}) \quad \text{(i)}$$

ϕ being obtained from the shear-box test. Thus each curve was asymptotic to

$$p_y = \frac{(1+\sin\phi)}{(1-\sin\phi)}\sqrt{p_x\,p_z}$$

For the case where $p_x = p_z = p_h$ this leads to the normal Rankine result; but the case of p_x and p_z being unequal may be regarded as one of the most interesting features emerging from this investigation, as purely theoretical considerations yield a completely different result. Thus, in the three-dimensional case, by considering the limiting conditions on a skew plane, it emerges that failure should occur whenever any pair of stresses attains the ratio K_r or $\dfrac{1}{K_r}$, whatever the value of the third. But in the foregoing experiments, with p_x and p_z maintained constant at different values, failure occurred when $p_y = \dfrac{\sqrt{p_x\ p_z}}{K_r}$.

As regards the lateral strains, for the cases of $p_x = p_z = p_h$ it was found that

$$\epsilon_h = -\,m_0 \log\left(1 - \frac{p_y}{C\,p_h}\right) - \frac{n\,p_y}{C\,p_h} \quad \text{(ii)}$$

For the sand used, C = 5, $k = 100$, $m_0 = n = 0{\cdot}009$.

In order to confirm the above work, a comprehensive series of normal tri-axial tests was performed, the results being added to the above curves, and were found to agree very closely with equations (i) and (ii) when $p_x = p_z$.

For the cases where p_x and p_z were different, it was found that, if all cases having the same value of p_x for the lower stress were grouped together, and the mean lateral strain calculated, then this mean was equal to the ϵ_h for the case of p_h = the lower stress.

Thus $\epsilon_{xy} = \epsilon_h + \epsilon$ and $\epsilon_{zy} = \epsilon_h - \epsilon$

Also ϵ was found to be $\left(1 - \dfrac{p_x}{p_z}\right)\epsilon_h$, whence

$$\left.\begin{aligned}\epsilon_{xy} &= \left(2 - \frac{p_x}{p_z}\right)\epsilon_h \\ \epsilon_{zy} &= \frac{p_x}{p_z}\,\epsilon_h\end{aligned}\right\} \quad \text{(iii)}$$

The above results were applied mathematically to the case of a cylinder with inelastic sides; since the stress-strain graphs of the sand are non-linear, the principle of superposition is only valid for small increments of strain. Hence, by differentiating the above equations, adding, and equating the lateral strain to zero, it was found that $p_h = \alpha\,p_y$, α being the solution of

$$\alpha\left\{\frac{1}{k\left(1 - \dfrac{C}{\sqrt{\alpha}}\right)} - (2-\alpha)\left[\frac{m_0}{(C-1)} - \frac{n}{C}\right]\right\} = \frac{m_0}{\left(C - \dfrac{1}{\alpha}\right)} - \frac{n}{C} \quad \text{(iv)}$$

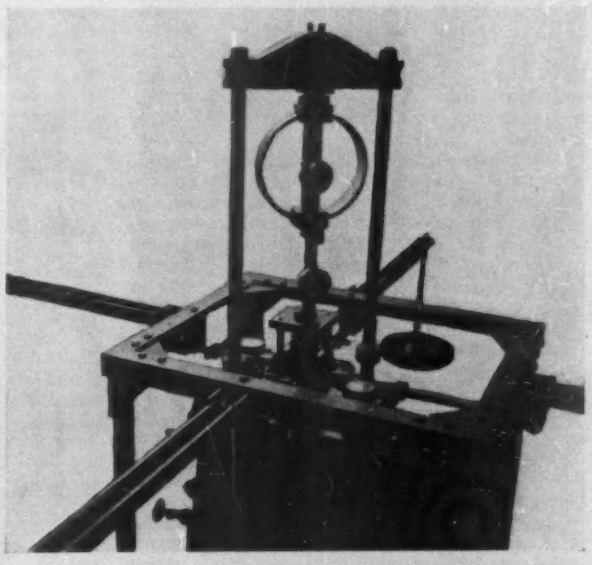
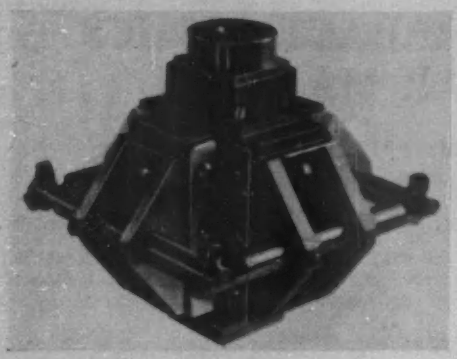


Fig. 1 General view of the apparatus. The lateral stresses are controlled by the size of the weights on the hangers.



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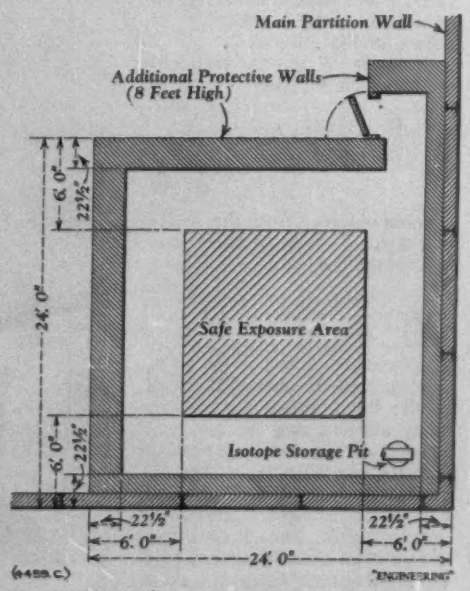

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The development and application of the Lincoln automatic plant are carried out in the Automatic Division to which is attached a demonstration room where students can learn to operate and maintain automatic welding heads, and where demonstrations based on customers' actual requirements can be set up. It can also be used for experimental work. Finally, there is a welding school for the training of operators.

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VERSATILE SPARK MACHINE

The GKN spark machine, designed by the Guest, Keen and Nettlefolds Group Research Laboratories and marketed by Rudkin and Riley, Limited, Cyprus-road, Aylestone, Leicester, has a work table 12 in. square, and a travel of 6 in. on the spindle. The electrode is carried in a V-block, and a feature of the design is the ease and speed with which a succession of electrodes can be set on a given workpiece. Copper is the usual material for the electrode, and with this material the wear rate is low, being in the region of 0·13 to 0·3 according to the cutting current. The machine is designed to operate on standard 400/440 volt, three-phase current, but it can also be supplied for non-standard voltages when required.

Input power is 2 kW, and the maximum cutting rate is about 75 cub. mm. per minute, at a standard of finish which is satisfactory for a large number of uses. Accuracy depends on the shape and accuracy of the electrode; in general, a tolerance of 0·002 in. can easily be held, and if required this figure can be reduced to 0·001 in. or even 0·0005 in.

The electric circuit is of the basic relaxation type, with special provision for reducing the tendency to arc, and there is no electronic equipment, either in the spark-generating circuit or in the servo-control. The machine table is connected to the positive lead of the circuit, and the electrode arbor to the negative side. All the head of the machine, except the table, is earthed, and the table itself, which is immersed in dielectric fluid when working, is insulated from the base of the head.

Control of the machine is very simple, and it is thus possible for operators to be trained quickly. There are on/off switches for the electrical circuit and the dielectric-fluid circulating pump, a four-position finish switch, and a multi-stage cutting-rate control. There is also an on/off switch controlling a vibrator unit, which is provided so that small oscillations can be superimposed on the servo drive. Normally, the vibrator is not used when cutting, but it has been found to be beneficial to use it when commencing a cut, or in difficult conditions, as in deep hole cutting, for instance.

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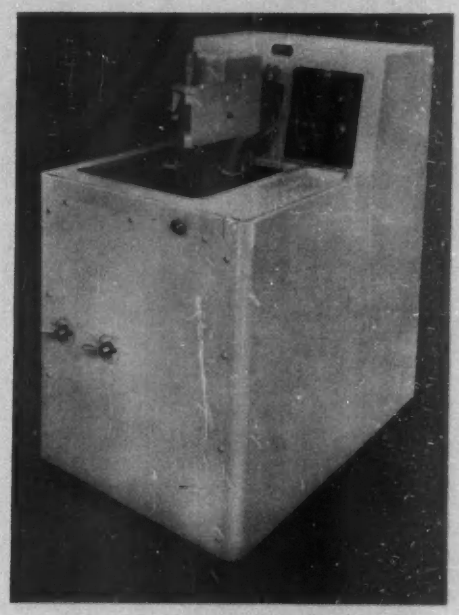
AIR DRYER

To avoid dampness in cellars, unheated buildings and other similar storage spaces, a unit-type air dryer has been developed by the Lightfoot Refrigeration Company, Limited, Abbeydale-road, North Circular-road, Middlesex. The unit will maintain temperatures down to and below freezing point, and is fitted with a simple auto de-frosting device; either automatic or hand-control can be arranged. A ¼ h.p. hermetically sealed refrigerating system is the operating mechanism, which is capable of removing up to 30 pints of water per day, depending on the relative humidity of the location. The units have overall dimensions of 1 ft. 1½ in. by 1 ft. 10 in. by 1 ft. 4 in. and are available for standard mains supplies. Various models for higher ambient temperatures where de-frosting is not required, and for domestic installations, are also in production.



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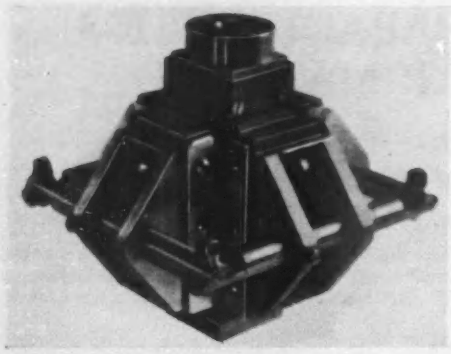

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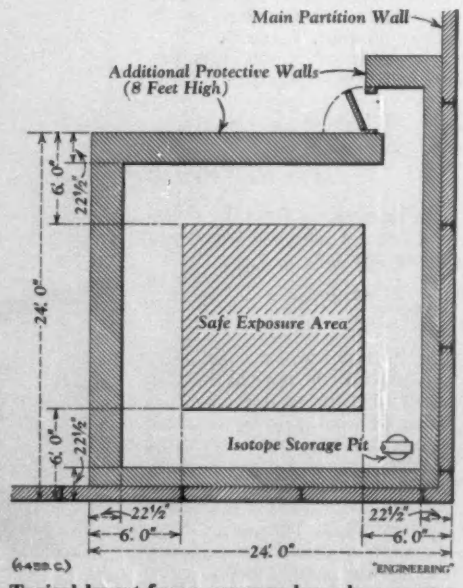

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The Production Quality Control Laboratory, as its name implies, is concerned with ensuring that all the fluxes and electrodes conform to manufacturing specifications. Operators from this laboratory are stationed in the various production sections under the control of the chief metallurgist and are empowered to reject sub-standard work and even completely to stop its manufacture. Finally, the mechanical and micro-scopical testing of weld specimens from the Production Control Laboratory, from experimental electrode development and for " approval certification " by Lloyds Register of Shipping and other authorities is carried out in the Metallurgical Laboratory.

In addition to the activities undertaken in these laboratories an Electrical Development Section has been formed to investigate the design and development of new electrical equipment for both factory and production purposes. It is responsible for prototype machines, obtaining test and performance figures and for setting standards required for the production machines. It also instructs the company's field engineers in the use and maintenance of new equipment.

The development and application of the Lincoln automatic plant are carried out in the Automatic Division to which is attached a demonstration room where students can learn to operate and maintain automatic welding heads, and where demonstrations based on customers' actual requirements can be set up. It can also be used for experimental work. Finally, there is a welding school for the training of operators.

* * *

VERSATILE SPARK MACHINE

The GKN spark machine, designed by the Guest, Keen and Nettlefolds Group Research Laboratories and marketed by Rudkin and Riley, Limited, Cyprus-road, Aylestone, Leicester, has a work table 12 in. square, and a travel of 6 in. on the spindle. The electrode is carried in a V-block, and a feature of the design is the ease and speed with which a succession of electrodes can be set on a given workpiece. Copper is the usual material for the electrode, and with this material the wear rate is low, being in the region of 0·13 to 0·3 according to the cutting current. The machine is designed to operate on standard 400/440 volt, three-phase current, but it can also be supplied for non-standard voltages when required.

Input power is 2 kW, and the maximum cutting rate is about 75 cub. mm. per minute, at a standard of finish which is satisfactory for a large number of uses. Accuracy depends on the shape and accuracy of the electrode; in general, a tolerance of 0·002 in. can easily be held, and if required this figure can be reduced to 0·001 in. or even 0·0005 in.

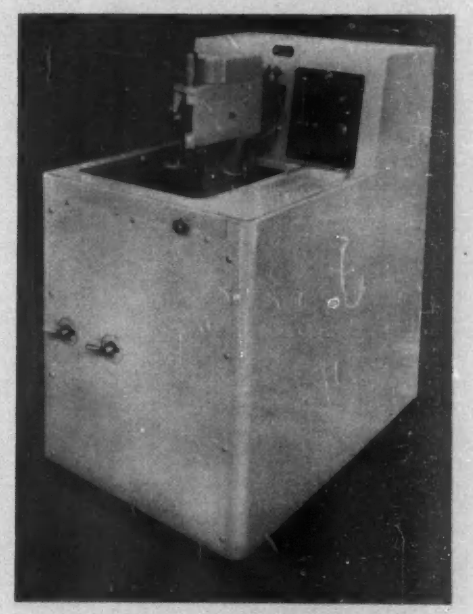
The electric circuit is of the basic relaxation type, with special provision for reducing the tendency to arc, and there is no electronic equipment, either in the spark-generating circuit or in the servo-control. The machine table is connected to the positive lead of the circuit, and the electrode arbor to the negative side. All the head of the machine, except the table, is earthed, and the table itself, which is immersed in dielectric fluid when working, is insulated from the base of the head.

Control of the machine is very simple, and it is thus possible for operators to be trained quickly. There are on/off switches for the electrical circuit and the dielectric-fluid circulating pump, a four-position finish switch, and a multi-stage cutting-rate control. There is also an on/off switch controlling a vibrator unit, which is provided so that small oscillations can be superimposed on the servo drive. Normally, the vibrator is not used when cutting, but it has been found to be beneficial to use it when commencing a cut, or in difficult conditions, as in deep hole cutting, for instance.

* * *

AIR DRYER

To avoid dampness in cellars, unheated buildings and other similar storage spaces, a unit-type air dryer has been developed by the Lightfoot Refrigeration Company, Limited, Abbeydale-road, North Circular-road, Middlesex. The unit will maintain temperatures down to and below freezing point, and is fitted with a simple auto de-frosting device; either automatic or hand-control can be arranged. A ¼ h.p. hermetically sealed refrigerating system is the operating mechanism, which is capable of removing up to 30 pints of water per day, depending on the relative humidity of the location. The units have overall dimensions of 1 ft. 1¼ in. by 1 ft. 10 in. by 1 ft. 4 in. and are available for standard mains supplies. Various models for higher ambient temperatures where de-frosting is not required, and for domestic installations, are also in production.



The GKN spark machine is designed for simplicity of operation, and has a minimum of controls.

CHIPPING OF HAND HAMMERS IN SERVICE

By A. H. Burn, A.I.M.*

In 1952 an accident occurred in which a workman lost an eye as a result of damage caused by a chip flying from the hammer he was using. Subsequent investigation showed that this hammer (shown in Fig. 1) had a hardness considerably greater than the maximum (namely, 640 V.P.N.) quoted in the relevant British Standard—B.S.876 : 1949, "Hand Hammers." The serious nature of this accident prompted the publication, some time afterwards, of an article in this journal.† This article drew attention to the dangers of using excessively hard hammers, the desirability of buying to specification where possible, and of providing adequate inspection designed to avoid the use of dangerous hammers and chisels.

More recently the occurrence of a further accident in which a 2 lb. ball-pein hammer chipped and caused the loss of the user's eye has re-focused attention on the question and particularly on the incidence of chipping at the edge of the striking face. This hammer (shown in Fig. 2) was of special interest in that subsequent examination showed that it conformed to the hardness and other requirements of B.S.876. This was disturbing, since previous occasional accidents of this nature had been associated with some clear deviation from B.S.876. By buying to this specification and by the adoption of a comprehensive inspection and testing procedure it had been thought that accidents of this sort would be eliminated.

As a result of the findings of this examination it was decided that an investigation into the state of hand hammers within the author's company was called for, with special reference to the incidence of chipping found and any relationship this might bear to the hardness of the hammers. In addition, information was needed on the mechanical properties of hammer steels at the high-hardness levels at which they are used.

SURVEY OF USED HAMMERS

Eighty-nine hammers, in use for various purposes, were withdrawn from service. The majority of the hammers obtained in this way were of the ball-pein type and of 1½ or 2 lb. weight. They were given a thorough visual examination, hardness tested and examined for cracks by the Magnaflux method. Finally, certain hammers were selected for more detailed examination, analysis, hardness distribution in section, and macro- and micro-examination.

The most important information, that relating to the degree of chipping found and the hardness of the hammers, has been assembled in Table I. In compiling this table, hammers with hardness of less than 510 V.P.N, and greater than 650 V.P.N. were considered as being "outside" specification. (The specification limits are 520-640 V.P.N. but it is reasonable to allow a little tolerance.)

TABLE I.—*Incidence of Chipping, Hardness of Chipped Hammers and Crack Test Results*

Hardness range	Below specification 279-490 Vickers pyramid numbers	As specified (+ small tolerance) 510-650 Vickers pyramid numbers	Above specification 652-974 Vickers pyramid numbers	Total
No. examined	3	42	44	89
No. chipped	1	18	24	43
No. cracked.. (Magnaflux)	None	None	None	None

* Metallurgical Section, Imperial Chemical Industries Limited, Billingham Division, Billingham, Co., Durham.

† "Hammers and Chisels," L. Smith, ENGINEERING, page 676, vol. 177 (1954).

No attempt has been made to allow for work hardening during service, as, at present, no information on this point is available. Hardness figures quoted refer to the edge of the striking face; where hammers were chipped the tests were taken in the vicinity of the damaged areas.

The variation in severity of chipping is shown in Figs. 3 and 4. In some cases the chips are small but this is no reason for considering them to be insignificant, as reference to Fig. 1 will show.

Magnaflux testing revealed no cracks in any of the hammers.

The high incidence of chipping in these representative hammers was not expected; previously it had been believed that a chipped hammer was a comparative rarity. It was found that both chipped and unchipped hammers occurred at any hardness level over practically the whole range, broadly speaking from below 500 V.P.N. to more than 800 V.P.N. This fact, illustrated by the figures given in Table I, would indicate that no particular merit attaches to the hardness range quoted in B.S. 876 as far as freedom from chipping is concerned. It may also be noted that hammers of hardness slightly below the specified minimum can chip, the chipping often being associated with mushrooming.

ADDITIONAL TESTS

In order to make absolutely certain that chipped hammers of normal hardness and free from obvious defects were not, in fact, deviating from B.S. 876 in some less readily detectable manner, further tests were conducted. These involved analysis, hardness distribution in section, macro-etching of sectioned hammers and micro-examination. Comparisons were made between chipped hammers of specification hardness, unchipped hammers of specification hardness, chipped hammers of excessive hardness and new hammers of specification hardness.

The analyses of representative hammers is shown in Table II and it can be seen that, except for one very minor exception (badly chipped hammer, high V.P.N., Mn content 0·81 per cent.), all hammers tested meet the compositional requirements of B.S. 876. These

TABLE II.—COMPOSITION OF REPRESENTATIVE HAMMERS

Description	Vickers pyramid numbers	C, per cent.	Mn, per cent.	Other elements (determined spectrographically)			
				Si, per cent.	Ni, per cent.	Cr, per cent.	Mo, per cent.
Specified limits	520/640	0·45/0·65	0·50/0·80	—	—	—	—
Unchipped hammer, normal V.P.N.	579/586	0·53	0·69	<0·10	N.D.	N.D.	N.D.
Badly chipped hammer, high V.P.N.	883/966	0·52	0·81	0·22	N.D.	N.D.	N.D.
Chipped hammer, normal V.P.N.	618/631	0·57	0·57	0·23	0·33	0·18	0·12
New hammer, "B"	Within B.S. 876 limits	0·50	0·54	0·20	0·13	0·10	0·09
New hammer, "N"	Within B.S. 876 limits	0·47	0·78	0·27	0·22	0·17	0·12

N.D. = Not detected.

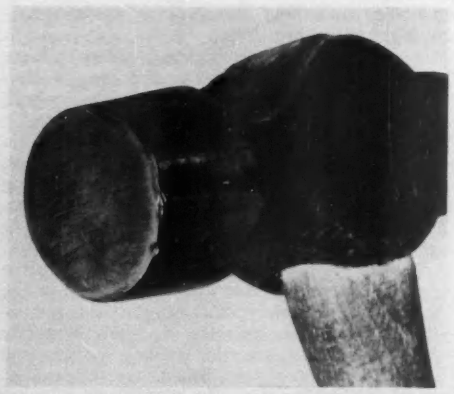


Fig. 1 Slight chipping of striking face of ball-pein hand hammer which resulted in the loss of an eye.

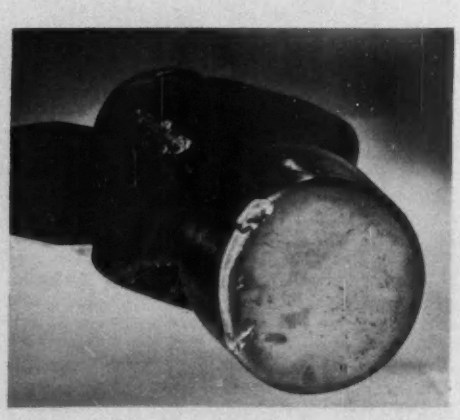


Fig. 2 Chipped 2 lb. ball-pein hammer which also resulted in the loss of an eye.

additional tests failed to produce any evidence to show that chipped hammers of specification hardness differed in any significant way from similar unchipped hammers.

While the investigation was proceeding, a case was reported of a new 1½ lb. ball-pein hand hammer chipping on the first occasion on which it was used and slightly injuring its user. The hammer was subjected to a detailed examination the main results of which appear in Table III;

TABLE III.—*Tests on New Chipped Hammer*

Test	Result		
Visual examination	Adequate chamfer and radius, no mushrooming, good condition apart from single chip at edge of striking face.		
Magnaflux	No cracks found.		
	Striking face		Pein
V.P.N. ..	Edge 550-594	Centre 618-622	635
Composition	C 0·60 per cent., Mn 0·61 per cent. (the spectrograph did not detect the presence of any alloying elements).		

as can be seen it conformed in all respects to B.S. 876. More recently, two further cases of hammers chipping and causing minor injuries to their users have occurred. In both hammers the hardness at the edge of the striking face ranged from slightly below to slightly above the maximum specified in B.S. 876.

ASSESSMENT OF PRESENT POSITION

The principal conclusion to be drawn from the results of this survey is that hammers complying with the current British Standard can and do chip in a dangerous manner. Moreover, the frequency with which such chipping occurs is far greater than had hitherto been supposed. While it was a known fact that very hard (i.e., untempered) hammers were prone to chipping,

hammers conforming to B.S. 876 were thought to be free from such a tendency. The fact that greater numbers of serious accidents have not resulted from chipping of " within-specification " hammers is purely fortuitous, and merely an indication that an eye is not always in the path of a flying chip.

If these collected results are representative of hammer performance in general, and there is no reason to think otherwise, it must be concluded that the application of the relevant British Standard does not produce hammers with the measure of safety in service which was the objective. Mere reduction in the specified hardness range would not, of itself, bring safety, since it has been shown that the softer hammers tend to chip as a result of " mushrooming." A reasonable deduction from the evidence seems to be that a better material is required.

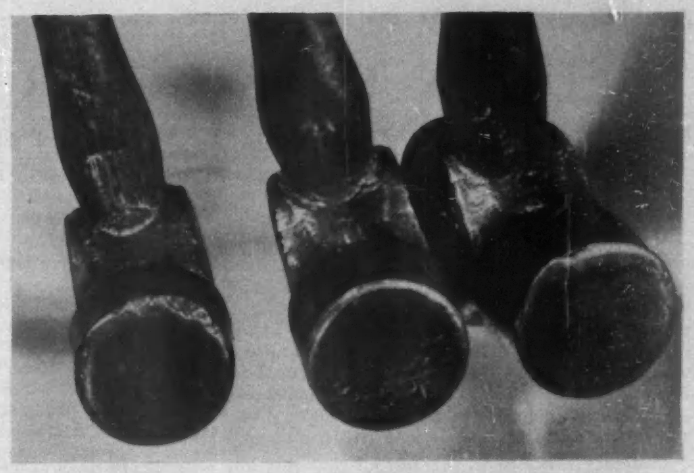


Fig. 4 Examples of chipping in hammers, the hardness of which conforms with the requirements of B.S. 876.

CONSIDERATION OF ALTERNATIVE MATERIALS

It seems likely that, if hammers were made of a steel which, at the required hardness and strength level, had greater ductility than the standard 0·55 per cent. carbon steel, they would be much less liable to chipping. To obtain a preliminary assessment of the possibilities in this direction, the mechanical properties of specimens taken from two 1½-lb. hammers (from different manufacturers) have been compared with specimens of 1 per cent. chromium-molybdenum steel. Other alloy steels are, of course, relevant and 1 per cent. chromium-molybdenum steel was used mainly because suitable bar was available.

Small tensile test pieces were prepared from blanks cut from two 1½ lb. ball-pein hammers of different manufacture and from 1 per cent. chromium-molybdenum steel bar. The blanks (four from each hammer-head and eight from the 1 per cent. chromium-molybdenum steel bar) were heat treated to give hardnesses of the order of 600 V.P.N. Tensometer test pieces were then produced from the blanks by precision grinding. Table IV gives the results of the mechanical tests. Specimens B 1 and B 2 became appreciably softened by heat generated during grinding and, as can be seen, gave tensile strengths of about 75 tons per sq. in. Even at this strength level their ductility was inferior to the much harder and stronger 1 per cent. chromium-molybdenum steel samples.

TABLE IV.—*Mechanical Properties of Tensometer Test Pieces (Hounsfield No. 11)*

Reference*	Ult. tensile strength	Elongation on 0·447 in.	Reduction of area
	Tons per sq. in.	Per cent.	Per cent.
B 1	75·2	10·5	10
B 2	71·2	10·9	25
B 3	136·8	3·4	Nil
B 4	131·2	2·1	Nil
N 1	108·0	1·2	Nil
N 2	108·0	2·3	Nil
N 3	102·4	3·5	Nil
N 4	90·4	1·1	Nil
CR 1	130·4	13·8	40
CR 2	122·4	12·2	45
CR 3	128·0	14·0	45
CR 4	131·2	14·3	40
CR 5	138·4	13·7	40
CR 6	138·4	14·8	43
CR 7	138·4	14·7	43
CR 8	137·6	14·7	45

* B = Hammer, maker " B "; N = Hammer, maker " N "; CR = 1 per cent. chromium-molybdenum steel bar.

These results clearly show the superior mechanical properties of 1 per cent. chromium-molybdenum steel at the hardness level under consideration. In particular the remarkable degree of ductility exhibited by this material (as measured by elongation and reduction of area values) is in marked contrast with the virtual absence of this property in both hammer steels. Further tests would, no doubt, provide additional useful information (for example, comparative impact tests at 600 V.P.N.) but it is considered that sufficient evidence is now available to allow the following conclusion to be drawn.

Hammers made from 1 per cent. chromium-molybdenum steel (and probably other low-alloy steels) can be expected to have greater resistance to chipping than the " 55 " carbon-steel hammers at present used.

FUTURE DEVELOPMENTS

The results of this investigation lead to the conclusion that the present material used for standard hammer heads is unsuitable and may have to be replaced by a low-alloy steel of the type of which 1 per cent. chromium-molybdenum steel is an example. Before such a change could take place it would be necessary to show by practical trials that the expected improvement does result. Work to this end is now in hand and a batch of about a hundred hammers made of 1 per cent. chromium-molybdenum steel to B.S. 970 En. 19 but conforming to the hardness and dimensional requirements of B.S. 876, is being produced. These will be issued to representative users and examined after a period of service. The results are awaited with interest. Such hammers will be more expensive than those of the present standard material but the additional cost can well be justified.

The present situation is undoubtedly far from satisfactory and, in the author's view, investigation of the possibilities of low-alloy steel as a potentially safer material than that at present used for hand hammers is well justified.

Fig. 3 Typical examples of severely-chipped hammers. Those marked with a tick are of normal hardness. Those marked with a cross are of hardness greater than 640 V.P.N. (Vickers pyramid numbers.)

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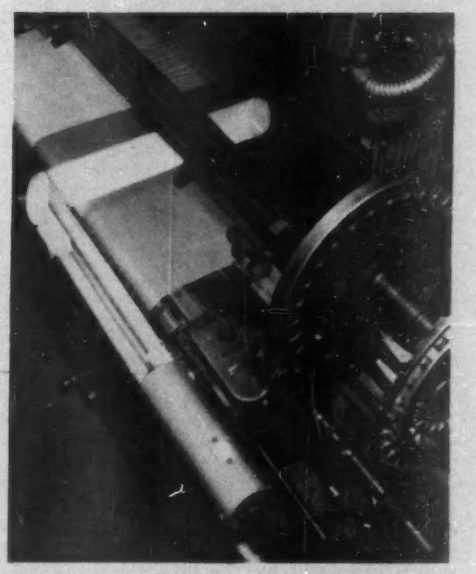
MACHINE SPOT LIGHT

For easy visibility of broken threads in the healds and reads of a loom, a light has been developed by Meiners Optical Devices, Limited, 121 London Wall, London, E.C.2, which illuminates only a few threads at a time. As can be seen from the accompanying illustration, the lamp-holder is mounted on the front of the loom, and the beam is directed across on to a mirror which reflects it on to the healds. A rail runs the width of the frame, carrying the lamp house at one end and also a slide on which the mirror is mounted. This allows the mirror to be moved from end to end of the rail, and the operator to examine any particular section of the frame. An automatic switch for the light is included, in the mirror. It is claimed that by concentrating the light on a small area, the correct drawing-in with minimum eye strain can be carried out, without excessive overhead illumination. Also the beam is not interfered with by the sley-cap or by the framework of the staves. The lamp is supplied from a 6-volt 50-watt transformer.



Small sections of a large area can be brightly lit by the lamp arrangement shown here on a loom.

Book Reviews

THANK THE WAR FOR THIS

Introduction to Operations Research. By C. WEST CHURCHMAN, RUSSELL L. ACKOFF and E. LEONARD ARNOFF. *John Wiley and Sons, Incorporated*, 440 *Fourth-avenue, New York* 16, *N.Y., U.S.A.* (12 dols.); and *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (96*s.*)

A wide interest is now being taken in Operational Research (Operations Research, as Americans usually call it; " O.R. " as we all call it). This interest is ill-served by the literature: most worthwhile O.R. writing has been written for the O.R. specialist. Thus there is more than room—there is a crying need—for a book about the subject which is both comprehensive and comprehensible.

Any such book should, however, be authoritative. This one is. It grew from material used in the short course on O.R. run yearly for the last five years at the Case Institute of Technology, and its parts were originally written by quite a number of eminent American O.R. men. The acknowledged authors have, however, not only collected the material, but have largely re-written it in an attempt to make the book a unified whole. This attempt largely succeeds.

Churchman, Ackoff and Arnoff are names highly respected in the international O.R. world. All three men are prominent Fellows of the Operations Research Society of America; Ackoff is President. Although he headed a mathematical department during the War, Dr. West Churchman was originally a philosopher. He returned to that subject as an associate professor before founding the O.R. Group at the Case Institute in 1951. Dr. Russell Ackoff (who studied architecture before turning to the philosophy of science) subsequently took over the direction of the Group, with Dr. Leonard Arnoff (a mathematician) as his associate professor. The Case O.R. Group has rapidly built a high reputation, and a book bearing these three names could hardly command more attention.

O.R. is an approach to the enormously difficult problems that arise in the doing of things. That is, the subject is not concerned with the static nature of plants and processes, but with their dynamic behaviour. The problems arise, then, not from difficulties in chemistry and physics, but from difficulties inherent in the system and from chance and mischance. Warfare is the prototype of this class of problem, and O.R. owes its genesis to the last War. Since then, other fields have yielded secrets to O.R.—notably in transport and productive industry. This book is concerned almost exclusively with industry.

" O.R. is the application of scientific methods, techniques and tools to problems involving the operation of a system so as to provide those in control of the system with optimum solutions to the problems." This is to be done by constructing a model of the system, and deriving the optimum system of behaviour from the model. It is a pity that the authors say explicitly a mathematical model, since (as they themselves later recognise, for example, in chapters 3 and 4) the model may be of any kind. It may be diagrammatic, or electrical, or logical for instance. The emphasis on the behaviour of systems as organic wholes is, however, most welcome. It is this emphasis alone which makes O.R. truly operational; it is this which so much other research lacks.

The point is well exploited in Parts I and II. Here the general nature of O.R. is discussed; and " general " does not mean " vague." Case histories are given which illustrate ably, in telling but not trivial detail, the key features of good O.R. There is a study of the production control problem in a machine tool factory, to show how all the interactions of a complex system must and can be taken into account. There is a brief examination of a problem in visual inspection, to show how this comprehensive analytic treatment draws on and integrates the knowledge of specialist members of the O.R. team. (The organisation of the team is shortly treated in the book's final chapter.) The way in which problems ought to be formulated, and the way in which the objectives of the study should be weighed, are discussed quite brilliantly.

Very special mention must be made of the treatment of the analysis of organisation. This rightly examines the problem in terms of communication, and draws equally on two analogies. Firstly, attention is directed to an organic model: the physiology of the nervous system. Secondly, there can be the servo-mechanism model, in which the control engineering concept of " negative feed-back " is applied. This is a thoroughly cybernetic approach to the question of organisation, which is nonetheless easy to understand; it is highly commended. The only criticism that might be made is that here, having decided to admit models which are not mathematical, the authors deny that a communications model is mathematical at all. This is surprising, as there is a large corpus of relevant work in the mathematical theory of information and the statistical treatment of systems, with which the authors are certainly conversant.

This first quarter of a long book is very important and entirely readable. The remaining three-quarters are devoted to the discussion of particular models. This portion begins with a detailed account of the structure of a model. It goes on to provide models for stock-holding, the allocation of resources and the analysis of delays. The development is fairly mathematical, and the engineer or manager may not wish to study the algebra. But a careful reading of the argument, and an appreciation of the numerous examples and case histories, will certainly reveal to him the gist of the subject and its importance. The same comments apply to the section on models for the replacement of parts, for competition, and for testing and control. The authors have been concerned not merely to " list " techniques; but the reader may be assured of the natural incorporation of all the key " tools of the trade," such as queue theory, linear programming, and the theory of games.

Here is a remarkable book, the only serious shortcoming of which is the absence of a full discussion in its own right of the concept which makes an O.R. model " tick "—probability theory. A statistical approach is implicit in the book; but the work would have gained from a lively discourse on the nature of probability. This is mainly a matter of emphasis; yet it is so important to understand that operational systems are not deterministic.

The book is directed partly towards potential O.R. practitioners. They would be irresponsible to their own careers if they did not study every chapter. But the main audience is the potential consumer. To the manager who wishes to understand this most important approach to his problems, the advice is: study the first 150 pages of the book, peruse the rest, and pass on the work to the most promising young man in the organisation. At any level of management, some sacrifice of high activity to the meditative pursuit of this programme might pay dividends.

AVOIDING THE IMPOSSIBLE

Mechanical Design for Electronics Production. By JOHN M. CARROLL. *McGraw-Hill Book Company, Incorporated*, 330 *West* 42*nd-street, New York* 36, *N.Y., U.S.A.* (6.50 dols.); and *McGraw-Hill Publishing Company, Limited*, 95 *Farringdon-street, London, E.C.*4. (49*s.*)

Much of the work of mechanical design applicable to the electronics industry could be termed an art rather than a science. Different designers have their own pet phobias, and their own interpretation of the " best " way to implement various design requirements. Common to all, however, are certain fundamental concepts which long experience of the behaviour-pattern of electronic equipments has made well-nigh mandatory.

Mr. Carroll has set out to group together in logical association, and to classify these fundamentals, and by and large he has succeeded. The mechanical engineer may find that the chapters dealing with machine shop and assembly line operations are lacking in completeness; the " i's " have not been dotted, and " t's " have not been crossed. But this book does not pretend to be a machine shop and assembly line *vade-mecum* and such a criticism, therefore, is hardly valid. The book's greatest merit is that if the electronics designer arms himself with the knowledge so clearly set out he will not present his mechanical colleague with an " impossible " design problem. For those engineers who have the double responsibility of electronic and mechanical design (their numbers are legion) the book provides a handy reference on production and assembly methods.

The design problem is examined in terms of commercial and military requirements. These broad divisions are sub-classified under the headings of ground, marine, mobile and airborne applications of electronic equipment, and limitations imposed by environmental factors such as humidity, altitude, ambient working temperature, vibration, shock, etc., are included. One would like to have seen fuller treatment of human engineering and automatic testing, but perhaps the arts associated with these are not sufficiently empiricised to provide a great deal of knowledge suitable for a text.

The fact that the book is obviously based on American experience and practice should not deter the British reader. It does mean, however, that the usefulness of some of the many tables is reduced. For example, drill sizes for tapping and clearing holes for American screws are of use only in the design of equipment using unified-thread screws, bolts, etc. On the other hand, one of the tables provides a cross-reference of American trade names for plastics with the plastics compound itself, and tables such as these provide an extremely useful feature of the book.

* * *

IN MEMORY OF A GIANT

Richard Trevithick " The Cornish Giant," 1771-1833. Memorials and Commemorations in Camborne and District. By J. F. ODGERS. *The Camborne Printing and Stationery Company, Limited*, 24 *Commercial-street, Camborne, Cornwall.* (2*s.*)

It is only in comparatively recent years that the massive contribution of Richard Trevithick to the history of engineering has come to be widely recognised. In the past his achievements have been overshadowed by those of other engineers, perhaps because Trevithick, though a brilliant engineer, was unsuccessful in the world of business, perhaps because other engineers had better biographers than he did, for it is on such chance matters that a man's fame can rest. Even to-day the work of Trevithick is not as well known in some circles as it should be. In his native town of Camborne, Cornwall, much has been done during the last 50 years to put his work in proper perspective, and his name and achievements are commemorated there in various ways.

The generosity of a few individuals and the patient work of a small number of historically-minded people have resulted in the activities of the great engineer being recorded in stone and bronze at appropriate points in and around Camborne. A statue of Trevithick stands outside the Public Library at Camborne, facing the hill up which his first locomotive ran successfully

in 1801; a plaque marks the spot on which the locomotive was built, and from which it set out on its historic journey; a further plaque stands on the site of the engineer's birthplace; and the cottage in which he spent several of his earlier years has been rescued from dereliction, and restored handsomely. How these various commemorative items came to be carried out is duly recorded in the booklet.

But there is another memorial to the work of Trevithick, still in the early stages of development, which should have a special appeal to engineers. This is the Trevithick Site Museum. In the care of the Cornish Engines Preservation Society in the Camborne district are two large Cornish beam pumping engines, a beam winding engine and a rotative beam pumping engine, together with a collection of other items which is small, but growing. Surely there could be no better memorial to Trevithick than examples of the engines and machinery which his genius made possible. The earlier memorials were only provided as a result of the help and generosity of interested people; the present one, most ambitious of all, has had similar support, but being a bigger undertaking it is in need of much more.

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NEW BOOKS

Engineering Uses of Rubber. Edited by A. T. McPherson and Alexander Klemin. *Reinhold Publishing Corporation*, 430 *Park-avenue, New York* 22, *N.Y., U.S.A.* (12.50 dols.); and *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (100*s.*)

Designed for the engineer and scientist outside the rubber industry, this book is also intended for the use of the technologist within the industry as it contains much information gathered from many sources. Eighteen rubber technologists have collaborated in the work, which deals with the applications of rubber and rubber goods in all branches of engineering. In addition, two chapters are devoted to the manufacture of rubber products and three to the properties and behaviour of rubber. The inspection methods and testing of rubber are also described, and, in a brief final chapter, the relations between the mechanical properties of polymers and their molecular structure are dealt with.

Water for Industry. Edited by Jack B. Graham and Meredith F. Burrill. *American Association for the Advancement of Science*, 1515 *Massachusetts-avenue, N.W., Washington* 5, *D.C., U.S.A.* (4 dols.); and *Bailey Brothers and Swinfen, Limited*, 46 *St. Giles High-street, London, W.C.*2. (36*s.*)

In view of the actual or threatened water shortage facing industry in the United States in the coming years, the American Association for the Advancement of Science invited a panel of specialists to present a symposium on the subject, at the annual meeting of the Association, held in Boston, in December, 1953. Nine papers were contributed by water, hydraulic, consulting and other engineers, and geologists, geographers and other scientific and technical persons, and these, together with two contributions to the discussion, have been collected and published in the present volume. The subject is dealt with entirely from the United States point of view, but such topics as the disposal of wastes in the atomic-energy industry, the disposal of industrial wastes, and technical problems in water-pollution abatement will be of interest also on this side of the Atlantic.

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TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Small Screw Threads. Anglo-Swiss Screw Co., Ltd., Trout-road, West Drayton, Middlesex. This is a reprint of a paper by Mr. R. R. Brierley, read at the 5th International Congress of Chronometry, Paris, 1954. It is concerned with small screw threads, from under 3 mm. to 0·25 mm. diameter, and covers thread standards, methods of production, and metrology. Illustrated wire-bound booklet, with stiff covers. Limited quantities available.

Spot Welder. W. D. Vick, Ltd., 28 Station-road, Acocks Green, Birmingham, 27. Light bench-type electric spot welder, in two sizes, 4 kVA and 8 kVA, the latter being recently introduced. The small machine has a capacity of two 16 s.w.g. sheets, while the larger will weld two sheets of 12 s.w.g. Illustrated leaflet.

Machine Tools. The Crowthorn Engineering Co. Ltd., Reddish, Near Stockport. Centre lathes from 7½ in. to 18 in., boring and facing lathes of 30 in. and 36 in. swing, 12½ in. combination turret lathe, 8½ in. parting-off boring and turning lathe. Also 19 in. shaping machine. Illustrated leaflet.

Laboratory Equipment. Thomas Robinson & Son, Ltd., Railway Works, Rochdale. Laboratory-type grinder, in two sizes, for material up to ¾ in. or 1 in. cube, and laboratory-type plan-sifter, suitable for testing or control of mill operations, or for research purposes. Two illustrated pages for the Robinson loose-leaf catalogue.

On the Shelf

By Frank H. Smith

There was a time when one could tell, from its title, from which firm a house magazine originated. Now, it is not so easy. The latest arrival is *Impulse*, from Mitchell Engineering, Limited, and I must say it has a very "contemporary" look. The contents have something to appeal to a wide audience and comprise "Related Values in Science and Art," "The New Lands of the Arctic," "Educating the Student Engineer," and an article on computers. Mitchell Engineering, by the way, are to build the first atomic reactor in West Germany. Their new journal can be obtained (price 10*s.* 6*d.*) from Journal Press, 5 and 6 Clement's Inn, W.C.2.

The Polytechnic Institute of Brooklyn, Department of Aeronautical Engineering and Applied Mechanics, has produced, in its Report No. 370, a list of the "Pibal" Reports 1948-57. This consists of a straightforward catalogue of Reports Nos. 120 to 370, giving the title and author of each paper and also where else it has been published; a subject index and an author index. For many years Professor Nicholas J. Hoff was the presiding genius at Brooklyn, which may account for the high percentage of papers on structures in the index.

A most attractive book has been issued by the Hymatic Engineering Company, Limited, of Redditch, called *Air is in the Air*. This gives an outline of the firm's history, products and methods, but I feel that the book's chief commendation is as an example of what modern publicity material can be. The printer's name should receive a mention but I failed to find it.

I wonder how much influence the Biggles books have on inspiring boys to join the Royal Air Force instead of becoming engine drivers? Jeremy Tinclair seems to think they might have some because he has written a book for boys and girls called *The Ghost of a Tangerine* which, he hopes, will sow the seed of civil engineering in the young mind. The background of the story is the Tangier mole, built in the reign of King Charles II by British enterprise, and a modern family's attempts to find out more about it. This is an unusual type of book for children and might well be the start of a series. How would youngsters react to a story about Telford's achievements, or those of Brunel?

From time to time the Science Museum Library issues a leaflet giving revised conditions of loan and other information of interest to borrowers. In the April issue there is a last paragraph that should be borne in mind when librarians are trying to decide what to do with periodicals for which they have no shelf space. "The Science Library is always on the look-out for volumes of periodicals needed to complete gaps in sets. If you possess anything not in our hand list, it will be welcome here if you do not need it."

The Science Library is a body in which every librarian in the country could well take a personal interest. It would be very pleasant to feel that we had the finest collection of its type in the world, not excepting such as the Library of Congress, and, though it may be rather late to talk of such things, why not form an organisation such as "Friends of the Science Library," whose aims would include the building up of the collection into complete coverage?

Trade literature, its filing and general control, is one of the constant bugbears of all librarians. It is refreshing, therefore to read that the R.I.B.A., in conjunction with the Building Centre, is organising a competition with the idea of raising the standard of such material used by architects and kindred professions. Further information may be obtained from the director, the Building Centre, 26 Store-street, London, W.C.1. In connection with the competition, all literature must comply with the provisions of B.S. 1311 (Sizes of manufacturers' trade and technical literature, etc.). Here, however, there may be a slight variance with the recommendations for an international standard. These are based on what is known as the "A" series, which uses a basic size of 841 by 1,189 mm. This series is already in use in 26 countries (17 have included it in their national standards) and it is to be considered as an alternative within B.S. 1311.

A sign of "progress" is the increasing rash of initials for identification. The technical librarian of Marconi's Baddow Research Laboratories has seen the need for a glossary of such abominations in his own particular field and has produced 37 pages of them, running from A.A.A. to Z.W.O. It applies chiefly to telecommunications, of course, but there are many sets in the book that have a wider application. This is the second edition and the booklet's growth in two years is quite frightening.

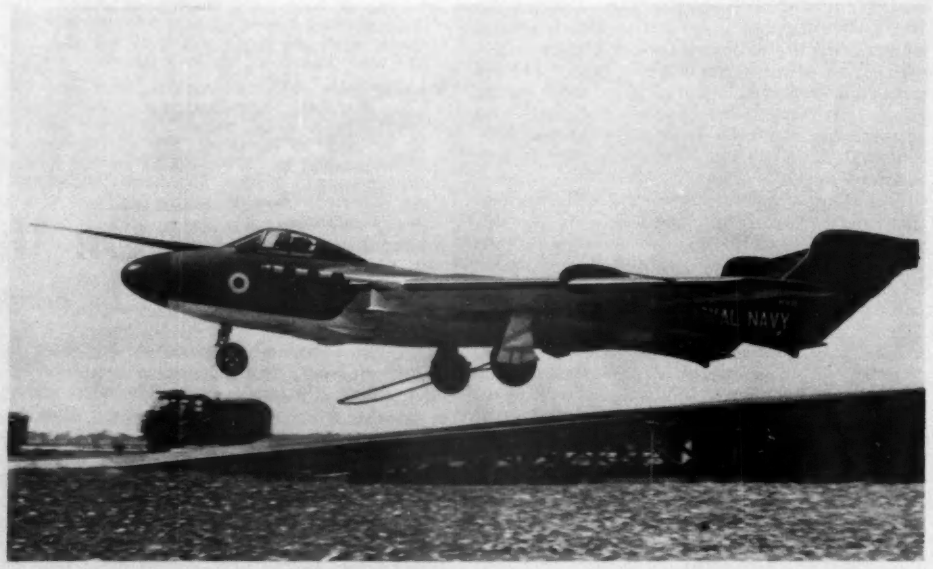
When one thinks of standards in this country one automatically mentions the British Standards Institution, but there are other bodies producing more specialist collections and among these is the Society of Motor Manufacturers and Traders Limited, 148 Piccadilly, W.1. Theirs is, naturally, intended for the trade served by the Society and at present constitutes some 200 pages divided into sections covering materials, metallic and non-metallic; tyres and wheels; electrical equipment; lighting and signalling; trailers; engine and chassis, and general items. The standards, in a loose-leaf binder, cost 2 guineas to members and 4 guineas to others, with an upkeep subscription of 21*s.* a year.

There is probably little that happened in 1956 of any note that is not covered—and covered authoritatively—in the excellent *Britannica Book of the Year*, 1957. The main headings are in alphabetical order and there is a 12 page index of the matters and personalities dealt with. Illustrations, of which there are plenty, are listed at the end of the book. The list of contributors at the beginning is imposing enough to form a "Directory of Authorities on All Subjects." To people who are accustomed to seeking information, such as librarians, the subject headings of the yearbook may be somewhat puzzling. They are too straightforward! Disasters of the year, for instance, are under the heading disasters. Incidentally those under "air" (they are divided into air, fires and explosions, marine, miscellaneous, natural, railways and roads) number 22. The other headings claim 8, 8, 6, 25, 11 and 5 mentions, respectively. A random glance through the book gives some idea of the subjects dealt with—Suez conflict, "rock 'n roll," exports and imports, drawing, engraving and illustration, book sales, diary of events of 1956, biographies, narcotics (which follows immediately on the review of popular music), engineering (heavy and light), television. There is, in fact, a year's reading; by which time you will be ready for the 1958 edition, covering 1957.

R.A.E. BEDFORD

High Speed Research

With the commissioning of the 8 ft. by 8 ft. high-speed wind tunnel at the Royal Aircraft Establishment, Bedford, recently, the facilities at Bedford have now been officially declared open by the Minister of Supply, as noted in last week's issue of ENGINEERING—although they have, in fact, been progressively brought into operation over the past few years. Some two years ago we had the opportunity of seeing over the Bedford tunnels and high-speed research laboratory, as they then were, and in the February 18, 1955, issue of ENGINEERING we described the 13 ft. by 9 ft. low-speed wind tunnel for investigating the low-speed behaviour of new shapes of aircraft; the 3 ft. by 3 ft. transonic/supersonic tunnel for speeds up to Mach 2; the vertical pressurised spinning tunnel —then just on the verge of completion—for investigating the spinning characteristics of free-flying dynamic models; the small supersonic tunnels of the high-speed laboratory which operate from the charging compressor of the spinning tunnel; and the 8 ft. by 8 ft. high-speed tunnel, then only partly constructed, which has recently been brought into operation. Because the 8 ft. by 8 ft. supersonic tunnel is a major engineering feat which has provided a stimulating task for many British heavy engineering and electrical firms, we are describing it in more detail in the article following this one.



The airfield attached to R.A.E. Bedford is also the base of the Naval Air Department and the Blind Flying Experimental Unit. Here, a DH 110 is seen taking off from the airfield by means of the Navy's only land-based steam catapult.

MACH 5 TUNNEL

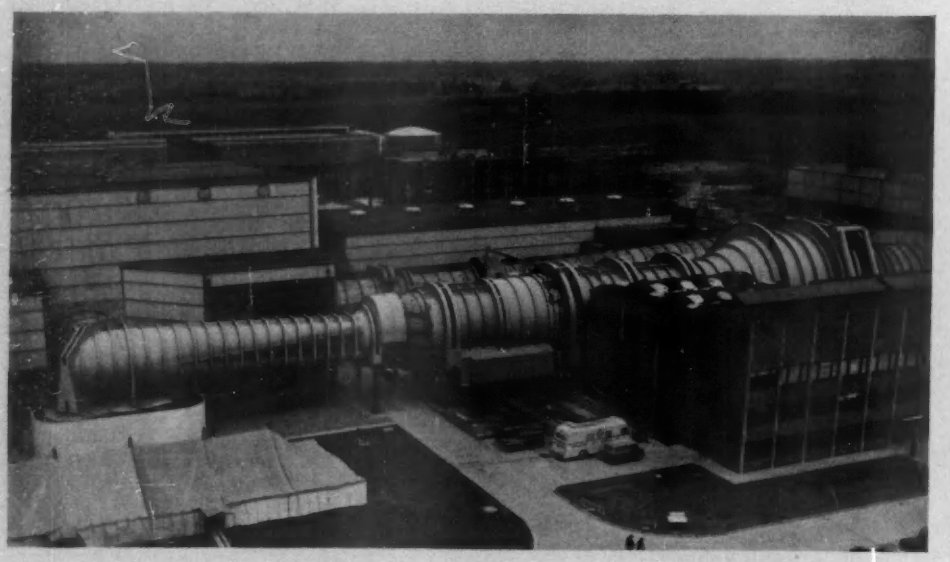
The 8 ft. by 8 ft. tunnel provides for speeds up to Mach 2·8, and since in advanced aeronautical thinking (in relation to missiles, for example) such speeds are verging on obsolescence, a new high-supersonic-speed tunnel is to be added to the facilities already described. This tunnel is now in the early stages of construction.

The high-supersonic-speed wind tunnel, with a nominal speed range from Mach 2·5 to Mach 5, will have a working section 4 ft. high by 3 ft. wide. The stagnation pressure varies from 5 atmospheres absolute at Mach 2·5 to 14 atmospheres absolute at Mach 5. The supersonic nozzle has flexible top and bottom walls. Air is circulated by two two-unit compressor sets which can be connected in series or in parallel. Coolers which keep the normal stagnation temperature down to 40 deg. C. can be by-passed to give air temperatures up to 150 deg. C. for running at high Mach numbers (to avoid liquifying of the air in the working section). A store of dry air at 4,500 lb. per sq. in. is used for charging the tunnel to the required pressure, and four reciprocating evacuators provide for reducing the tunnel pressure before starting up or shutting down.

The two sets of compressors will have driving motors totalling 88,000 b.h.p. Each set comprises a low-pressure axial compressor and a high-pressure centrifugal compressor driven at a maximum speed of 3,000 r.p.m. by a two-pole 34,000 b.h.p. synchronous motor and a six-pole 10,000 b.h.p. slip-ring induction motor driving through speed-increasing gears. The induction motor will be used to drive the set up to synchronous speed and thereafter to contribute part of the power required to drive the compressors, the load carried being regulated by a continuously rated liquid controller. The maximum duty of the two sets of compressors, with the compressors in each set working in series, is a combined inlet volume flow of 336,600 cub. ft. per minute at an overall pressure ratio of 17 to 1. For work at lower Mach numbers in the range Mach 2·5 to 3 the two compressors of each set can be operated in parallel to give an increased volume flow at a lower pressure ratio.

In the working section the nozzle will be adjustable to cover the whole Mach number range from 2·5 to 5, being formed by top and bottom flexible plates wrapped round a solid block of suitable contour at the throat. The throat gap and contour of the flexible plates downstream of the throat will be regulated by servo-controlled electrically-operated jacks. The top and bottom flexible plates, which are of stainless iron, slide between parallel vertical side walls of the same material. Unlike the working section of the 8 ft. by 8 ft. wind tunnel, this nozzle will not be contained within a separate pressure shell since enclosing the jacks and their driving and control mechanism within an atmosphere of air at 150 deg. C. would introduce many difficult problems. The absence of the outer pressure shell, on the other hand, introduces a difficult sealing problem between the side walls and the top and bottom flexible plates, and extensive use will be made of dry-air sealing at these sliding seals as well as at compression glands and flange joints throughout the circuit.

The method of air drying is compression to 4,500 lb. per sq. in. in six-stage reciprocating compressors, followed by chilling to 5 deg. C. to reduce the moisture content to 0·00005 lb. of water per lb. of air. The dry air will be stored at this pressure in six strip-wound vessels each 45 ft. long by 48 in. in internal diameter until required for purging or charging the tunnel circuit.



This Mach 2·8 wind tunnel has recently been commissioned at R.A.E. Bedford.

ENGINEERING SERVICES

At present electrical power up to 75 MVA, for operating the tunnels is taken at 132 kV from Little Barford power station, through a two-mile-long gas-pressurised underground cable; on site it is transformed down to 33 kV before reaching the main sub-station, from whence it is distributed to the various buildings and the airfield, generally at 11 kV.

To cater for peak-load requirements, and to permit operation over a wide range of frequencies a variable-frequency generating plant, supplied by the English Electric Company Limited, will shortly be commissioned. The plant comprises two 20 MW gas-turbine-driven alternators generating at 11/2·2 kV and 50/10 cycles per second, and an associated sub-station.

Water supply requirements to replace the evaporation and carry-over losses from the cooling-tower installations are estimated at 750,000 gallons a day. Water pumped from the intake works on the Ouse at Sharnbrook is treated for temporary hardness by the addition of lime, and is then stored in two covered 500,000 gallon reservoirs at ground level. To provide a head for the distribution of water throughout the site, a 50,000 gallon service tank is provided at the top of the 80 ft. high vertical spinning tunnel, between the top dome of the pressure shell and the floor of the motor room above. The water level in this tank is maintained automatically by booster pumps, with a total capacity of up to

60,000 gallons per hour, from the ground-level storage reservoirs.

In addition to the general maintenance workshops and the local workshops attached to each major installation for day-to-day modifications, there is a large main workshop equipped with an extensive array of high-precision machine tools for making new equipment. One of their most exacting tasks is the manufacture of models, in materials ranging from woods and synthetic resins to 55–60 ton per sq. in. steel forgings, to very close tolerances. A high-tensile steel model with internal drillings for pressure tappings, may take up to 6 months to prepare. Spark-machining techniques are used for difficult shapes.

AIRFIELD ACTIVITIES

As well as the wind tunnel and laboratory facilities, R.A.E., Bedford, includes an airfield and associated facilities for flight development testing, with a 10,500 ft. runway—one of the longest in Europe. Here, the whole of the flight test work of the R.A.E. aerodynamics Department is carried out—problems associated with low-speed flight, take-off and landing, transonic and supersonic flight, and stability and control; the Blind Flying Experimental Unit, who are currently working on the problem of automatic speed control of the aircraft during the final phase of landing during an approach in bad visibility, and the Naval Air Department, also make use of the runway.

Among the airfield facilities of the Naval Air Department is the only land-based steam catapult—which has a 200 ft. stroke—in Europe, two arrester gears and a safety barrier and arrester-gear proving base. Not only are naval aircraft proved on these facilities, but also development work is carried out on the carrier-borne equipment itself. A second steam catapult is being installed to investigate the problem of using a much higher steam pressure. The safety barrier experience of the Navy is now being developed for land-based aircraft, to arrest them should they find themselves " running out of concrete." For this purpose, the plastic extension (up to 300 per cent. of the original length) of un-drawn nylon rope, arranged in a series of rectangular loops, is used to absorb the aircraft's unwanted energy.

* * *

INTERNATIONAL COUNCIL OF THE AERONAUTICAL SCIENCES

Under the aegis of the Institute of the Aeronautical Sciences (United States), an International Council of the Aeronautical Sciences has been formed recently.

Sixteen representatives of 10 nations—Canada, France, Germany, Great Britain, Holland, Italy, Spain, Sweden, Switzerland and the United States—met in Paris on May 30 as a Provisional Council of the first world-wide organisation formed specifically to extend collaboration in all scientific fields relating to mechanical flight. Dr. Theodore von Kármán has been elected honorary president, and M. Maurice Roy (France) is chairman of the executive committee. The Institute of the Aeronautical Sciences will act as the permanent secretariat of the ICAS and provide the operating staff.

The first International Congress of the new organisation is to take place in Madrid in September, 1958. Subsequent congresses will take place in other countries biennially.

Funds towards the support of the ICAS are being made available through the Institute of the Aeronautical Sciences from a substantial donation by Mr. Harry Guggenheim in whose honour the ICAS has established the Daniel and Florence Guggenheim International Memorial Lecture, which will be presented by an outstanding aeronautical scientist at each International Congress.

CLOSED-CIRCUIT WIND TUNNEL FOR SPEEDS FROM ZERO TO MACH 2·8

EUROPE'S LARGEST " PRESSURE TUNNEL "

The 8 ft. by 8 ft. closed-circuit high-speed wind tunnel (Fig. 1) commissioned recently at the Royal Aircraft Establishment, Bedford, and said to be the most advanced of its type in Europe, is large enough to permit control surfaces and other design details to be properly represented on complete models of up to 6 ft. span. It is intended to provide information for the design of high-speed aircraft—or more fundamental data on basic shapes—over a speed range from zero to Mach 2·8, excluding the transonic region, and the air density can be varied to give the maximum Reynolds number at all speeds, consistent with the model strength or the power available. The stagnation pressure can be varied from 0·1 to 4 atmospheres absolute, and the working-section region of the tunnel is enclosed in an outer pressure shell to reduce the loads on the working-section walls.

The nozzle for generating supersonic flow in the working section has its top and bottom walls made of flexible steel plates each 1 in. thick, supported on a number of hydraulically operated screw jacks which can be adjusted to provide a continuous adjustment of supersonic Mach number. The uniformity of the air flow in the working section depends critically on the shape of the nozzle walls, and an elaborate control system is used to set the jacks accurately to the required positions.

The working section is followed by a supersonic diffuser, which is made adjustable to improve the efficiency of pressure recovery, and it is preceded by a large settling chamber, giving a contraction ratio of 16 to 1, which is fitted with fine wire gauge screens for reducing turbulence. The working section can be bypassed by bleeding air from the settling chamber and returning it to the main circuit through injector slots in the diffuser. This bypass is used for matching the compressor characteristics at high Mach numbers, and at the same time it improves the performance of the diffuser.

The air is circulated by a ten-stage axial-flow compressor, which is built in two parts, so that the six high-pressure stages can be shifted out and replaced by a plain section, leaving four stages in the circuit. This considerably improves the compressor efficiencies at the lower pressure ratios required for Mach numbers below about 1·6. The compressor is driven by electric motors totalling 80,000 h.p., and there is under development a 53,000 h.p. gas-turbine generating station which will permit considerable flexibility in the driving arrangements.

The temperature of the air at the compressor outlet may reach 160 deg. C., and arrangements are provided to allow for the free expansion of the tunnel shell on its supports. A large cooler before the settling chamber reduces the stagnation temperature to 40 deg. C., and is designed to give a practically uniform temperature distribution over its outlet area.

The auxiliary plant includes compressors and evacuators for providing the required stagnation pressure in the tunnel, and dryers for maintaining the air humidity at the lowest possible value, to minimise effects of condensation in the working section.

TUNNEL SHELL

The tunnel, believed to be the largest pressure vessel in Europe, is generally of circular cross-section varying in diameter from 20 ft. at the compressor inlet to 47 ft. at the tunnel cooler, and forming a closed circuit with four rectangular corners. The two long legs of the circuit are 350 ft. and the two cross legs 60 ft. between centres. The total structure weight is about 5,000 tons. In selecting the material, particular care has been taken to use steels that are not susceptible to brittle fracture, and for the thicker plates (above $\frac{1}{2}$ in.) Coltuf was selected, the lighter plates being of boiler-quality steel. Specially-trained welders were employed to fabricate the shell, and every seam was examined radiographically.

The tunnel circuit was broken down into a number of cylindrical and conical sections, and each section was prefabricated in a vertical position. When completed, the sections were lifted and rotated into position by a 200 ft. high derrick crane, and were attached by cleats before the final circumferential welds were made.

The pressure shell is rigidly anchored to the foundations at the compressor, the cooler, and the two corners upstream of the compressor. Elsewhere it is carried on supports which allow freedom of movement in one or more directions (Fig. 2). Changes in longitudinal length of the

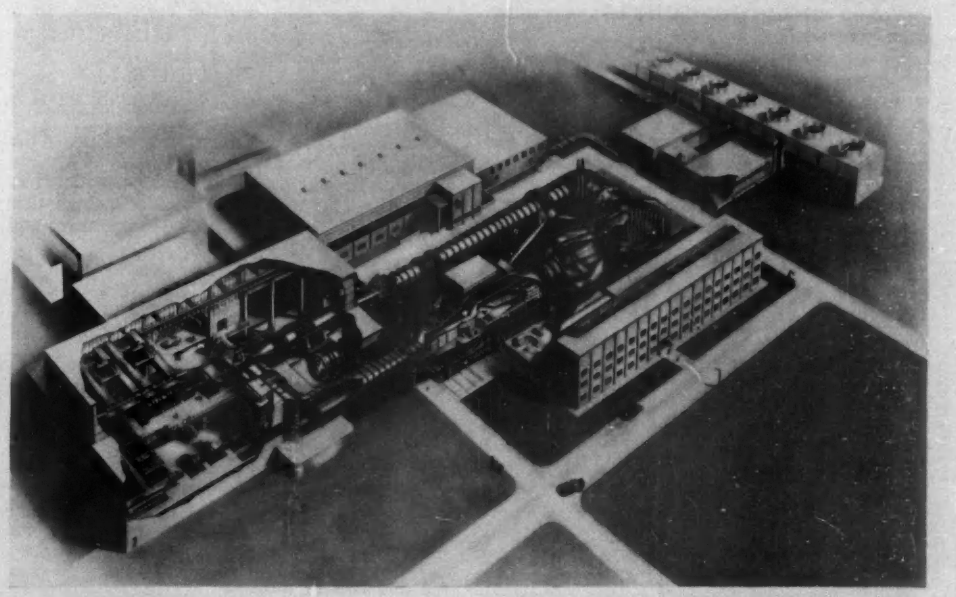


Fig. 1 A cut-away model of the R.A.E. variable-density closed-circuit wind tunnel, which has an 8 ft. square working section. The tunnel has flexible-wall nozzle which enables tests to be made at a speed range from zero to Mach 2·8 (excluding the transonic region).

Fig. 2 Supports for the structure were designed to allow for freedom of movement (except at the compressor, the cooler and the two corners upstream of the compressor, where the pressure shell is rigidly anchored).

shell between anchor points are absorbed in five expansion joints. The maximum movement to be accommodated is of the order of 5 in. and the minimum ¼ in. The joints handling the smaller movement are of the bellows type. Sleeve type joints, sealed from leakage by inflated rubber seals, are used for the larger movements, and one compressed-rubber joint is used.

Hydraulic tests, with strain gauge readings, of the tunnel pressure shell were carried out in three sections as construction of each section was completed. The open ends of each section were blanked off with hemispherical ends. For the main hydraulic test (which covered all the structure apart from No. 1 diffuser and the section from No. 1 to No. 2 corner, dummy casing, and compressor) filling required 2¼ million gallons of water and took three days. A final examination showed satisfactory water tightness at 75 lb. per sq. in. absolute with satisfactory results, but inspection of the resin applied to the welds showed some slight cracking of welds on the radial weld stiffeners at Nos. 3 and 4 corners. It was decided that this was mainly due to locked-up weld stresses and the cracks were subsequently repaired.

Finally an air-pressure test at 1·1 times working pressure was carried out on the complete structure with all expansion joints free to move. Apart from the H.P. and L.P. compressor sections which are included in the pressure shell, and had not been hydraulically tested, the structure was found to be sound and tight. Repairs subsequently carried out to reduce the leakage at the compressor proved successful.

TUNNEL COOLER

The duty of the tunnel cooler is to reduce the temperature of 1,200 lb. of air per second from 160 deg. C. to 50 deg. C. The air leaving the cooler has to have a uniform velocity and temperature. The cooler is of the plain tube type with air passing through the tubes, the cooling water flowing around the tubes in two double reversed-flow passes. The pressure shell is at this point 47 ft.-diameter and the two main tube plates (each 2½ in. thick) and the three baffle plates forming the water passes are welded into it. The total length of the cooler is 16 ft. 6 in., and it contains some 58,000 tubes expanded and welded into the 32 in. square tube plates. The water flow is 1¼ million gallons per hour, the temperature rise being 9 deg. C. from 25 deg. C. maximum inlet temperature.

The whole of the cooler was fabricated on site, starting with the welding of the plates to form the tube plates, marking out and jig drilling the holes, threading the tubes and expanding and welding them in position. Special lifting tackle was designed for handling the tube plates without distorting them, since two-thirds of the original metal in the drilled areas had been removed.

WORKING SECTION

The working section nozzle (Fig. 3), which is contained within the pressure shell of the tunnel, consists of two fixed side walls and top and bottom walls which can be flexed to form a convergent/divergent nozzle, this being the means by which speed in the supersonic range is controlled. (At subsonic speeds, control is by the speed of the compressor driving the air round the tunnel.)

Each flexible plate, 8 ft. wide by 64 ft. 8 in. long, and 1 in. thick over most of the length, forming the top or bottom wall of the nozzle is made from two Ducol plates butt-welded together to give the required length. The airswept surfaces are finally coated with Araldite, a thermal setting synthetic resin giving a smooth hard protective coating. This operation was carried out on site in a specially constructed oven 68 ft. long by 9 ft. wide by 4 ft. high, incorporating seventy 2¼ kW tubular heating elements to provide the heat for curing the Araldite after spraying.

Across the back of each flexible plate are welded 31 T-shaped stiffeners, to each of which (except the first, which is the upstream attachment point) are attached two 3½ in. diameter 2 t.p.i. screw jacks which are used to support and flex the plates. The effective pivot points of the jack attachments lie on the neutral axis of the plate. There are 30 jacking stations, each consisting of the two screw jacks on one T-shaped stiffener on the top plate and the two jacks on the corresponding stiffener on the bottom plate. The jacks are driven in pairs through reduction gearing by hydraulic motors controlled by sensitive valves, which in turn are simultaneously controlled electrically by punched tapes and modified telegraph tape readers.

The whole series of operation is automatic once the operator has selected the nozzle profile required on the Mach number selector and pressed the start button. The system moves the walls from the existing setting to the new setting and automatically stops when the new setting has been reached. An extra punched tape is used to control the Mach number selector, holes in this tape being punched to correspond to increments of 0·01 of Mach number which are displayed on a Mach number indicator.

The maximum movement of each wall is 2 ft. 11 in.; each impulse corresponds to a movement of each wall of 0·0025 in. (0·00125 in. for the nine downstream stations where the total travel is much less) giving a total of 14,000 steps for the complete travel; the operating speed is 390 impulses per minute.

To obtain operating experience and prove the stability of the electro-hydraulic control system, a prototype jacking station was constructed at Bedford. This station consisted of a single pair of jacks with a complete individual control and hydraulic system. After proving tests had been carried out the station was used to life-test the specially developed equipment. Resulting from experience obtained during the test, the thread form of the main screw jacks was changed from square to a modified Brown and Sharp, and the material of the main nuts from cast iron to leaded bronze.

To prevent the plates being over-stressed during flexing, a curvature gauge is fitted on to the back of the flexible plates close to each T stiffener. The gauges provide signals which give continuous indication of the stresses in the plate due to the curvature and, in the event of the radius of curvature at any point becoming so small that the maximum safe stress in the plate is exceeded, they bring the movement of the flexible walls to a halt. A routine check of each gauge is made automatically on change of Mach number.

The side walls, which are 62 ft. 6 in. long and 8 ft. 6 in. high, stand 8 ft. apart and are joined by top and bottom portal frames into a rigid structure weighing approximately 400 tons. Both the top and bottom portal frames which carry the main jacks are constructed and assembled in five groups, the hydraulic installations being complete and tested before final erection in the tunnel. The whole working-section structure is supported at three points inside the pressure shell, which at this part of the circuit is 30 ft. in diameter; the downstream support is fixed and the others are two roller supports.

Lifting the flexible plates into the tunnel and erecting them in position had to be carefully planned to avoid over-stressing the plates. Initially, strongbacks were fitted to the plates to enable them to be lifted by the derrick and then held on the lifting blocks and carried into the shell. Then, in a predetermined order, the jacks were attached to take the weight of the plate, and operated by hand to set the plates in their initial position. Portable curvature gauges were used to ensure that the safe maximum stress in the plates was not exceeded when operating the jacks by hand to bend the plates to the correct shape of inlet flare.

SUPPORTING THE MODEL

The model, weighing up to 1 ton, is mounted on a sting supported in a gear quadrant which is housed in a 15 in. wide centre fairing in the supersonic diffuser, downstream of the working section. The quadrant is driven by two hydraulic motors through an arc of ± 22·5 deg. to enable the angle of incidence of the model to be varied over that range, and the movement is controlled by coarse/fine magslips to an accuracy of ± 0·025 deg. In a similar system the angle of roll of the model can be varied over a range of ± 180 deg. with an accuracy of ± 0·125 deg. The model-support sting can be replaced by a calibration probe which has an electro-hydraulically controlled axial travel of 8 ft.

A battery-operated trolley is used to bring the model, complete with sting, from the rigging room through the main tunnel-access door into the supersonic diffuser. The trolley is equipped with hydraulic rams for raising and lowering the model and with five manual adjustments

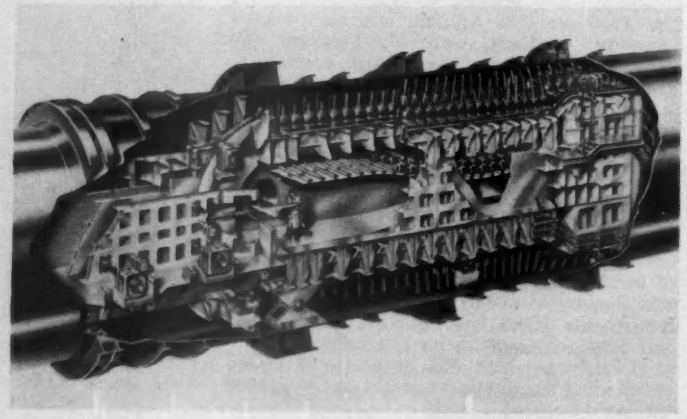


Fig. 3 The flexible-plate nozzle, model-support section and supersonic diffuser. Air speed in the supersonic range is controlled by flexing the top and bottom walls to form a convergent/divergent nozzle.

so that the model and sting can be offered up to and mounted in the sting housing.

The model is viewed indirectly through a periscope system and by a closed-circuit television system; there is also a schlieren light system which displays the air-flow pattern round the model. The pressure distribution over the surfaces of the model is measured by orifices connected to manometers and strain gauges measure the stresses in the model (all these readings are automatically recorded) and a six-element balance has been provided to calibrate the strain gauges and to separate the lift, drag and side forces and the pitching, rolling and yawing moments. The pressure distributions along the air swept-surfaces of the contraction, working section and supersonic diffuser are displayed in the observation room on a manometer installation including over 40,000 ft. of $\frac{1}{8}$ in. diameter copper tubing.

SUPERSONIC DIFFUSER

After passing over the model the air passes through the supersonic diffuser which, acting as the reverse of the convergent/divergent nozzle in the working section, slows the air down to subsonic speeds. If this is done efficiently it saves as much as 10,000 h.p.

The supersonic diffuser, like the working section, is contained within the main tunnel pressure shell. The diffuser is 59 ft. 3 in. long and consists of fixed top and bottom walls, connected by side frames into a rigid structure, with moving side walls, each consisting of five sections, the longest of which is 25 ft. long and the shortest 5 ft. long, hinged together and moved by screw jacks. The screw jacks are driven by hydraulic motors in a manner similar to the flexible-plate jacks. The control is from additional holes punched in the working-section control tapes, enabling the diffuser walls to be automatically set to the desired position for a particular Mach number. For the supersonic diffuser there are only three jacking stations each of two jacks for each side wall, the maximum movement of each jack being 2 ft. 6 in. steps 0·05 in. at a maximum rate of 1·8 in. per minute. The diffuser is 8 ft. square at the upstream end which joins the working section and diverges to 10 ft. 4 in. square at the downstream end which leads into a subsonic diffuser.

The tunnel structure can be split at circumferential bolted flanges at each end of the supersonic diffuser; and the whole structure, weighing approximately 800 tons, and carried on a 32 wheel truck, can be moved out of the circuit and parked so that it may be replaced by another diffuser section.

To obtain operating experience and enable the optimum positions for the supersonic-diffuser moving walls to be determined, a working model of the working section and diffuser was constructed having a working section 13 in. square. Electric motor-driven jacks controlled by cam-operated micro switches were used to bend the flexible plates and electric motors, manually controlled by the tunnel operators, were used to position the diffuser moving walls.

MAIN COMPRESSOR: REMOVABLE HIGH-PRESSURE ROTOR

The main compressor, the largest of its kind in Europe, is a ten-stage axial machine designed to develop a pressure ratio of 2·63 to 1 with an inlet volume flow of 2,730,000 cub. ft. per minute at a maximum speed of 750 r.p.m. The compressor is built in two sections—a four-stage low-pressure (L.P.) section fixed permanently in position, and a removable high-pressure (H.P.) section of six stages. To give more efficient working at pressure ratios below 1·47 (corresponding to a speed of Mach 1·6 through the working section), the L.P. section only is used, the six H.P. stages being replaced by a dummy section. For pressure ratios of 1·47 and above, all ten stages are used.

The rotor blades are machined from 1 per cent. chromium steel (En18) forgings; there are 53 per stage; the blade height varies from 2 ft. 5 in. at stage one to 2 ft. for stages 5–10; each blade weighs about 1 cwt.

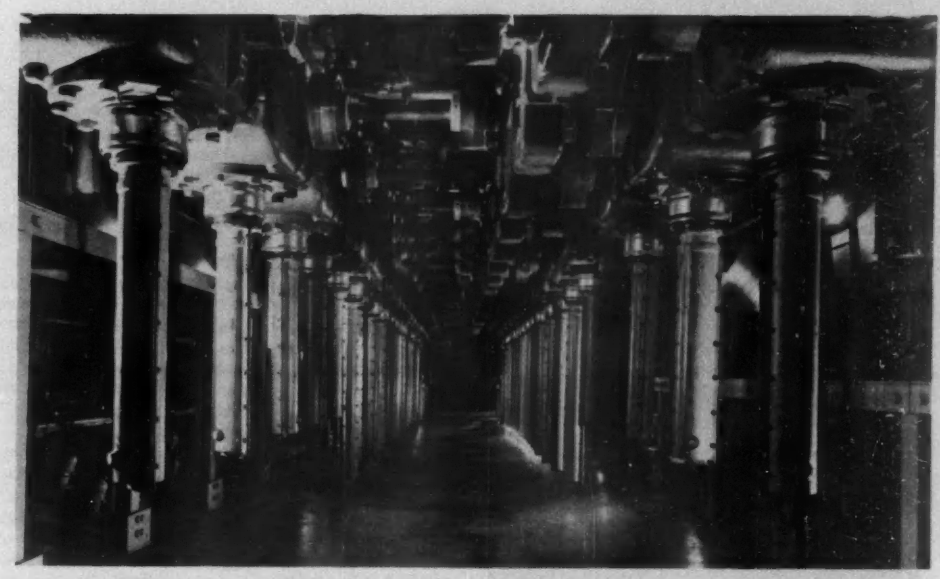


Fig. 4 Jacking stations for the bottom flexible plate of the adjustable nozzle section.

The intermediate shaft coupling is specially designed to accept up to $\frac{1}{2}$ in. misalignment between the low and high-pressure rotors, and to enable the rotors to be coupled and uncoupled quickly. In practice, the actual misalignment between the rotors is not greater than 1/32 in. The shaft is permanently engaged in the H.P. rotor and is moved into engagement with the L.P. rotor by a motorised oil pump acting on a piston, a single guide tooth on the intershaft ensuring that the shaft engages correctly. When in position, a metal-to-rubber-face bellows-type seal is made to close off the L.P. outlet and H.P. inlet bearing housing chambers and the chamber containing the intershaft from the tunnel air stream. The seal is retracted as required by a motorised oil pump acting on three radial pistons.

The L.P. and H.P. compressor stator casings, which form part of the tunnel pressure shell, are split in the vertical plane at flanges which are fitted with heat-tightened bolts. The half casings, each weighing 41½ tons in the case of the L.P. and 47 tons for the H.P., can be traversed outwards on tracks for a distance of almost 9 ft. to facilitate inspection of the rotor and stator. The L.P. stator consists of a pre-stator row followed by four stator rows; the H.P. stator consists of six stator rows. There are 52 blades to each row, produced from En18 forgings.

When the compressor is working as a four-stage machine the H.P. section is replaced by a cylindrical section of tunnel shell known as the "dummy section," the whole operation taking about 20 minutes to complete. The H.P. and dummy casings are mounted on a wheeled truck, normally connected together, running on guide rails laid in the main concrete foundation block which at this point is 18 ft. thick. The two running rails are 90 ft. long and have 12 in. wide faces.

The overturning movement resisted by the L.P.-section bearing pedestals during tunnel operation can be as high as 780 ton-ft. Heavy steel monolith fabrications are therefore used, set deeply in the concrete which, under the L.P. section, is 23 ft. thick (the thickness here, however, being dictated largely by the heavy loading applied by the adjacent tunnel corner). The truck is traversed by a 3 h.p. induction motor and reduction gearbox located at the side of the rail and driving through a pinion on to a rack. The maximum speed of traversing is 4 ft. per minute, which is automatically reduced as the truck approaches the end of its travel. When the H.P. or dummy section is in stream, the truck is held rigidly in position by four pairs of clamps, each pair being driven through high-reduction gears by one reversible electric motor. Before the truck can be traversed it must be jacked up through a distance of $\frac{7}{8}$ in. on to its wheels which are relieved of load when the truck is in stream. The truck-jacking operation is accomplished hydraulically by a non-reversible motor-driven oil pump and arranged so that the two jacks move together to keep the truck level. The H.P. section and its truck weigh 600 tons; the dummy casing and its truck weigh 96 tons.

INFLATABLE SEAL

The operations for exchanging the H.P. and dummy sections are carried out from a control desk adjacent to the compressor, and the sequence of operations is fully interlocked to ensure that each operation is successfully completed before the next is started. To enable the H.P. and dummy casing to be interchanged, the joints

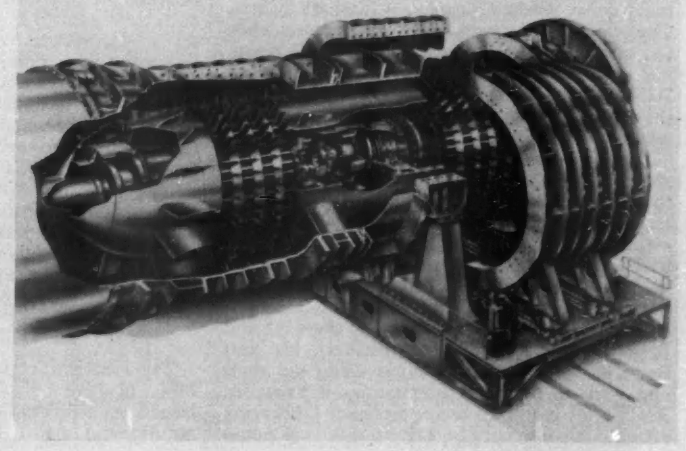


Fig. 5 The axial-flow compressor which drives the tunnel. The entire six-stage high-pressure section can be removed and replaced by a dummy section for more efficient operation at speeds below Mach 1·6.

Fig. 6 The main compressor drive motors: the compressor is directly coupled to a 68,000 h.p. synchronous motor which is connected through a gearbox to two 6,000 h.p. D.C. motors in tandem.

between the moving portions and the fixed portions of the L.P. compressor and tunnel structure have to be broken. For this, two quick-release rubber-to-metal inflatable circumferential seals have been provided. A keystone section rubber ring is fitted at each end of the H.P. and dummy section casing. Against each of these, when in stream, is forced a steel ring of rubber-bonded to two similar rings which are bolted to an annular water box. One water box is bolted to the tunnel structure at the H.P. compressor outlet and the other is bolted to the L.P. compressor-outlet bearing casing. By pressurising the water box, the centre ring moves axially until it presses against the sealing rubber strip. The system is arranged so that, in the event of pressure failure in the lines outside the seals, spring-loaded valves close and lock the seals in the extended position, thus preventing an uncontrolled opening of the tunnel circuit during pressure or vacuum conditions. The operation of a " jettison " control switch quickly breaks the seals by de-energising the make-up and circulating-pump motors and opening the pressure-relief valves.

LUBRICATION AND SHAFT SEALS

The L.P. and H.P. rotors are each mounted in two white-metal journal bearings with a fixed pad thrust bearing combined with the L.P. inlet and the H.P. outlet end journal. On starting, each journal is initially hydraulically jacked and the main lubricating oil to both journal and thrust bearing is supplied by an electrically-driven flood pump. There is also a " mechanical " flood pump driven from the main drive gearbox through a layshaft system. The electrically-driven pump cuts out when the compressor speed has risen to 200 r.p.m. and cuts in again when the speed falls below 200 r.p.m. or in the event of failure of the shaft driven pump. Jacking oil is also brought in again as speed falls.

Also fed from the lubricating-oil system is the shaft seal. The compressor drive-shaft passes through the tunnel shell, and to prevent air leakage between the tunnel and atmosphere, oil is supplied by an electrically-driven pump to flood the annulus between the shaft and the shaft-seal housing in the drive-shaft tube. Part of the oil to the shaft seal flows along the shaft into the L.P. inlet bearing-housing chamber and back into the L.P. oil tank reservoir, but part flows in the opposite direction along the shaft and back to the main lubricating-oil reservoir. As this oil is lost to the compressor-lubricating system, an electrically driven make-up pump operating automatically from float switches in the L.P. compressor oil tank maintains the correct oil level in both L.P. and H.P. tanks.

Oil mist or vapour must not be allowed to leak into the tunnel air stream, so the bearing labyrinth glands are packed with dry air bled from the tunnel, and the bearing system is scavenged so that it is always below tunnel pressure; thus dry air is drawn into the bearing oil-drain chambers, carrying with it the oil mist from the bearings.

The necessary vacuum in the oil tanks is maintained by a vacuum pump or scavenge evacuator. When tunnel pressure rises above atmospheric a non-return valve in the evacuator by-pass line opens and flow is established to atmosphere through an orifice. The evacuator is shut down by a pressure switch when tunnel pressure reaches 17·8 lb. per sq. in. absolute, and the leakage from the tunnel through the compressor glands is then controlled by the orifice only. To prevent " motoring " of the evacuator, and hence uncontrolled air flow, a solenoid valve in the suction connection to the evacuator also closes at this pressure.

With tunnel-operating pressures varying between 1·47 and 60 lb. per square inch absolute at compressor outlet, and with the bearing system scavenged so that all leaks are inwards through the glands from the tunnel, the pressure of the oil in the tanks under the L.P. and H.P. compressors varies over a wide range and can fall to as low as 0·9 lb. per sq. in. absolute. The mechanically and electrically-driven flood pumps drawing from these tanks are approximately 9 ft. below the oil level, but even so, at the low tunnel densities the effective pump-suction condition can fall to 22 in. Hg. vacuum. Commissioning runs have disclosed that it is essential to have good venting of the lubricating-oil system from the pump to the lubricating-oil tank to release entrained air and to avoid cavitation.

DRIVE MOTORS

The compressor is directly coupled to a 68,000 h.p., eight-pole synchronous motor which in turn is connected through a single-stage double-helical gearbox to two 6,000 h.p. direct-current motors in tandem, energised in a simple series loop by two similar machines acting as generators and driven by a 14,000 h.p. 11 kV ten-pole synchronous motor.

Under reduced-load conditions the compressor can be driven by the direct-current machines alone over the full designed speed range of 150/750 r.p.m. with the 68,000 h.p. motor electrically disconnected. For high-power working the 68,000 h.p. motor can be run at a fixed speed of 750 r.p.m. from the grid supply, with the direct-current motors acting as pony motors to run the compressor up to synchronising speed, and contributing 12,000 h.p. to the drive. Both alternating-current and direct-current motors will be used for variable-speed working by connecting the 68,000 h.p. motor to a variable-frequency supply which is available from two 20 MW gas-turbine generating sets.

Facilities for both hand and automatic control of speed are provided, the design accuracy of the automatic control system being 0·1 per cent. of set speed. When working with the variable-frequency alternators, the direct-current machines operate under automatic control with either manual or automatic control of the gas-turbine. Under manual control of the gas-turbines, remote operation of the gas-turbine fuel control valve is effected through a Selsyn link to take up major changes of load beyond the capacity of the direct-current machine. Under fully-automatic control, the error signal, in addition to adjusting the excitation of the direct-current generators, also controls the fuel-valve setting on the gas-turbines.

AUXILIARY PLANT

Two identical sets of Howden-Lysholm helical-lobe positive displacement evacuators (the largest yet built) reduce the tunnel pressure from atmospheric down to 0·1 atmosphere. Each set deals with about 45,000 cub. ft. of air per minute and together the two sets can reduce the tunnel pressure from 14·7 to 1·47 lb. per sq. in. absolute in about 11·1 minutes. The four L.P. evacuators can also be arranged to run in parallel to drive a 13 in. high-speed tunnel which is a one-seventh scale model of the 8 ft. by 8 ft. tunnel.

Two centrifugal compressors, are used to pressurise the tunnel. Running singly or in parallel gives mass flow rates of 12, 24 and 36 lb. per sec. of air at 31 lb. per sq. in. absolute; running in series they give about 23 lb. per sec. at 60 lb. per sq. in. absolute. To charge the tunnel from 1·47 to 14·7 lb. per sq. in. absolute takes 13·2 minutes; from 14·7 to 30 lb. per sq. in. absolute takes 14·6 minutes, and from 30 to 60 lb. per sq. in. absolute takes 43·6 minutes. These compressors were used for pneumatic tests on the tunnel shell to produce the maximum test pressure of 64·5 lb. per sq. in. absolute.

Two identical Howden-Lysholm compressors are used to control tunnel pressure to counter the effect of outward leakage when operating at pressures above atmospheric, and run in conjunction with one evacuator set to maintain minimum humidity conditions in the tunnel when operating sub-atmospherically. Each compressor delivers approximately 2·5 lb. air per second at 60 lb. per sq. in. absolute.

All air admitted to the tunnel is dried to a humidity less than 0·0002 lb. of moisture per lb. of air. The drying plant is divided into two main sections—charging and trimming—with a common refrigerating plant. Both the charging and the trimming sections consist of two adsorber vessels, with after-heater and pressure-regulating valve, by which drying is carried out at constant pressure and independently of tunnel pressure. Each adsorber vessel consists of a brine cooler, silica-gel bed and built-in heater for the reactivation cycle. The refrigeration plant can extract 7,500,000 B.Th.U. in 24 hours from a storage tank containing 17,000 gallons of calcium chloride brine which is used for air pre-cooling and gel reactivation.

Induced-draught cooling towers and circulating pumps provide for the dissipation of 500,000,000 B.Th.U. per hour from the water circulated through the main tunnel cooler and the many water coolers associated with the 8 ft. by 8 ft. tunnel plant. For the tunnel cooler, in which the tubes are mild steel, a small chemical dosing plant has been provided to inject sodium hexa-meta phosphate as a corrosion inhibitor.

The main contractors were:—tunnel shell and main air cooler, Whessoe Ltd.; main compressor and electric drive, English Electric Co. Ltd.; 11 kV and 3·3 kV switchgear, English Electric Co. Ltd.; flexible-plate nozzle, supersonic diffuser and associated hydraulics, Costain-John Brown Ltd.; electrical control system for nozzle and supersonic diffuser, General Electric Co. Ltd. Research Laboratories; rewinding of German D.C. motors, and generators, Baldwin & Francis Ltd.; air-drying plant, Silica Gel Ltd.; main charging compressors, Daniel Adamson & Co. Ltd.; trimming compressors and evacuators, James Howden & Co. Ltd.; cooling towers, Film Cooling Towers Ltd.; circulating water pumps, Pulsometer Engineering Co. Ltd.; air and water pipework, Whessoe Ltd. and Simmonds & Hawker Ltd.; air and water valves, Alley & MacLellan Ltd. and J. Blakeborough & Sons Ltd.; 80 ton electric cranes, Babcock & Wilcox Ltd.; 50 ton and smaller cranes, Wharton Crane Co. Ltd.; model strain gauge calibration gear, Sir Howard Grubb Parsons & Co. Ltd.; periscope optical systems, Barr & Stroud Ltd.; closed-circuit television cameras and monitors, Pye Telecommunications Ltd.; model-handling trolley, Harborough Construction Co. Ltd.; goods/passenger lift, Evans Lifts Ltd.; electric power and control cables and electrical services, London Electricity Board; heating services, J. Jeffreys & Co. Ltd.; buildings and tunnel foundations, Higgs & Hill Ltd.

The main contractors for the variable-frequency generating station were:—gas-turbine generating plant, English Electric Co. Ltd.; fuel-storage installation, Costain-John Brown Ltd.; 65 ton crane, Babcock & Wilcox Ltd.; electric power and control cables, Cable Jointers Ltd.; electric services, London Electricity Board; heating services, Stitson White Ltd.; building and plant foundations, Higgs & Hill Ltd.

INTERNATIONAL CONGRESS ON COMBUSTION ENGINES

2—SUPERCHARGING THE DIESEL

Concluded from page 798, June 21.

The features of the turbo-charging system used on the M.A.N. engines were described by Dr. Ing. E. Soerenson. Much has already been published on these engines, but some more experience has since been obtained with them in service. A charging air pressure greater than 28 lb. per sq. in. absolute is employed, and the b.m.e.p.'s are in excess of 170 lb. per sq. in. Fuel consumption was as low as 0·31 lb. per b.h.p.-hr. This high degree of supercharging has been applied to engine sizes ranging from crosshead types of 17·7 in. bore and 26 in. stroke running at 250 r.p.m., to trunk piston types of 7·1 in. bore and 7·9 in. stroke running at 1,500 r.p.m. Dr. Soerenson pointed out that high pressures had been chosen as they meant lower exhaust temperatures and it was easier to deal with mechanical rather than thermal stresses. A 16-cylinder V-engine, after 4,000 hours running, showed a ring groove wear of only 0·35 mm. per 1,000 hours and a bore wear of 0·06 to 0·08 mm. per 1,000 hours. The rate of wear was unchanged by the increased pressures. Comparable results had been obtained using pistons with various arrangements for oil cooling. Asked whether he thought that the two-stage compressor would compete economically with the single-stage machine or with two single-stage machines in series, Dr. Soerenson was emphatic that it would not.

In a paper which gave much practical and theoretical information, Mr. H. Herga and Dr. E. Jenny described the development of turbo-charging by Brown, Boveri and Company since the first charger was built in 1923. Mr. Herga emphasised the thermal limitations of power from the exhaust and said that they had found the pulse system to be definitely the better for engines with 6, 9 or 12 cylinders for charging ratios greater than 3 : 1 and also in cases of low load when a high increase was wanted. Much work had been done in silencing. No fewer than 15 speakers took part in the subsequent discussion, and consequently the authors' replies were very much curtailed. However, Mr. Herga said they chose to use the piston crown temperature as the criterion for thermal stresses rather than that of the liner, as there was some doubt as to the consistency of such a figure. Criticised for using ball bearings, rather than plain sleeves, he replied they were chosen on account of their simpler lubrication arrangements, and because they were less liable to oil losses or ingress of dirt. On the question of the method of fixing the blades in the rotor, he said that they preferred mechanical fixing of the fir-tree type, but this was not possible with small sizes.

The Götaverken engine described by Mr. Eric Johansson in conjunction with Mr. L. G. Thulin was the only opposed-piston machine mentioned at the conference. It was designed particularly for a specific weight not exceeding 6·6 lb. per s.h.p. and for a peak output of 3,000 s.h.p. on a half-hour rating. The final choice was a ten-cylinder supercharged two-stroke opposed-piston engine with two crankshafts and a bore of 180 mm. (7·09 in.) and stroke of 2 × 230 mm. (2 × 9·055 in.). The speed was 975 r.p.m. with 100 per cent. supercharge. The two crankshafts are joined by spur gearing, the upper pistons controlling the exhaust ports and the lower pistons the scavenging ports. Supercharging is supplied by an exhaust turbo-charger operating on the equal pressure system with, in addition, a compressor driven directly from the engine to supply additional air at low powers and speeds. The transmission for this compressor includes a hydraulic clutch and two free-wheel clutches since the engine is directly reversing and the compressor must, of course, always rotate in the same direction.

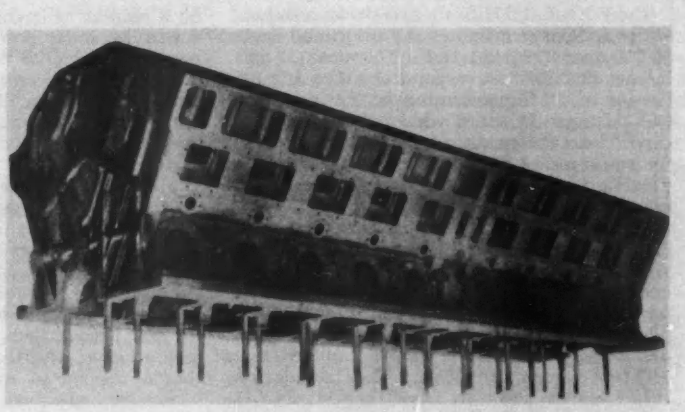
After building the first engine it was decided both to reduce the weight and to increase the power. The latter was done by increasing the bore to 185 mm. and the speed to 1,000 r.p.m. The weight was reduced by using welded components instead of castings and by substituting chromium-plated steel liners for the cast-iron ones previously used. By these means a maximum power of 3,250 s.h.p. and a continuous rating of 2,800 s.h.p. were achieved for a specific weight, including compressors, pumps, coolers and filters, of 5·65 lb. per s.h.p. (maximum rating). This engine showed a fuel consumption of 0·366 lb. per b.h.p.-hr. at an output of 2,750 h.p.

The gear train between the two crankshafts consists of five wheels. The two on the shafts themselves have their rims and hubs connected by sets of radial leaf springs between which are wings attached to the hub but free to slide against the rim. The whole of the interior of the gear is filled with lubricating oil. This arrangement acts as a suppressor for torsional vibrations. There is also a vibration damper fitted to the free end of the upper crankshaft, and the three together reduce the torsional vibration forces in the crankshafts to less than 1,400 lb. per sq. in. over the full speed range of the engine. For the small end bearing a special needle bearing was designed. The fastening of the gudgeon pin was made by pressing into its ends light-metal plugs with a thermal coefficient of expansion greater than that of the material of the piston body. Consequently the gudgeon pin will be slightly expanded under normal working conditions. To compensate for this expansion a small taper is ground on the ends of the inner bearing ring so that the needles carry an equal load along their length. In answer to a question, Mr. Johansson said that they had experienced some corrosion of the steel cylinder liners by the cooling water but this had been overcome by the use of an additive.

News of developments in Japan was contained in a paper given by Mr. Hideo Fujita, of the Mitsubishi Shipbuilding and Engineering Company, Limited. The engine he described was the 9UET, a highly supercharged trunk-piston single-acting engine working on the two-stroke cycle. It was designed to give 6,000 h.p. at 380 r.p.m. with a specific weight of 24·25 lb. per b.h.p. For normal running a turbo-charger, also of Mitsubishi's design, is used but for slow speed and manoeuvring a separately driven compressor is employed. Ahead and astern running are controlled by shifting the camshaft backwards or forwards and in addition to the ordinary manoeuvring handle there is a cut-off lever which stops the fuel supply to six of the nine cylinders, in effect converting the engine to one of three cylinders only. In this condition, and using the auxiliary blower, stable running at speeds as low as 6 knots with the engine developing 50 or 60 h.p. can be achieved. Bore and stroke of the engine are 440 mm. (17·32 in.) and 550 mm. (21·65 in); the piston speed is 1,372 ft. per min. and the b.m.e.p. 134·3 lb. per sq. in. During sea trials a fuel consumption of 0·346 lb. per b.h.p.-hr. was attained at an output of 4,500 b.h.p.

An interesting feature of the turbine characteristic curve is that there is an area of negative pressure in the range where the flow quantity is small. This indicates that the turbine acts as a blower in this region and so tends to reduce the back pressure of the engine during the scavenging period, with the result that the scavenging action is improved. An adiabatic efficiency of 82·5 per cent. was obtained for the blower at the design point.

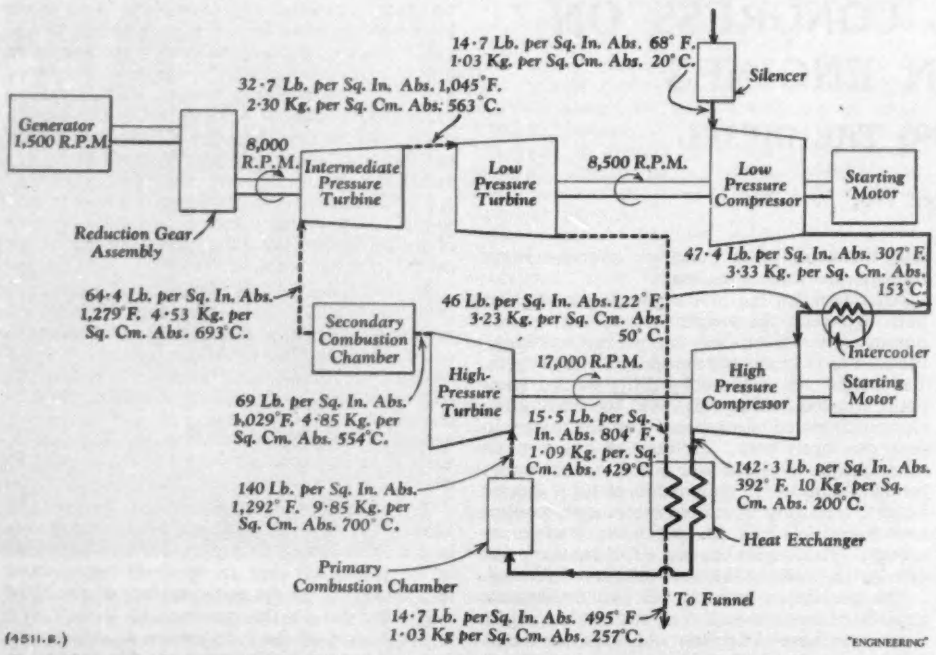
Temperature measurements made during tests showed that the top ring area of the piston was in the 200–250 deg. C. region. It was suggested in the discussion that an apparent temperature of 250 deg. C. at the water surface of the head might be due to the presence of a very thin layer of scale of the type known to occur with cast-iron but not with aluminium. No experience had been obtained running the engine on heavy oil.



The main block of the Tokyo ZC 2,000 b.h.p. engine is a single casting which was tested for stresses by using strain gauges.

Experiences with two other Japanese engines were described in subsequent papers, one by Mr. I. Yamashita of the Mitsui Shipbuilding and Engineering Company, Limited and the second by Mr. K. Okamura of Mitsubishi Nippon Industries, Limited. The first was a B. & W. type nine cylinder two-stroke engine, developing 6,000 h.p. at 350 r.p.m. and a maximum of 6,600 h.p. at 361 r.p.m. Bore and stroke were 500 mm. (19·7) and 600 mm. (23·6 in.) and the m.e.p. was 104 lb. per sq. in. The total weight of 75 tons was equivalent to a specific weight of 27·6 lb. per b.h.p. During tests some of the compressor blades of the turbo-charger fractured, caused, it was suggested, by running too close to the critical speed with consequent blade vibration—an example of the necessity for matching the engine and the turbo-charger exactly.

The second engine was the Mitsubishi Tokyo ZC, also a marine engine but of V formation having two banks of ten cylinders and producing 2,000 b.h.p. at 1,600 r.p.m. This is equivalent to an output of 0·565 b.h.p. per sq. cm. of piston area. The scavenging and supercharging is provided by a turbo-charger and a Roots blower (driven from the crankshaft) in series. These are mounted in the V of the engine and the specific weight of the whole is approximately 6·16 lb. per b.h.p. Intense swirl is provided at the top of the cylinder by three rows of inlet ports, the angles of which were chosen by experiment. The two-stroke cycle is used and there are four exhaust valves in the head operated by two push rods. The stresses in the cast engine block were determined by strain gauges.


14·7 Lb. per Sq. In. Abs. 68° F.
1·03 Kg. per Sq. Cm. Abs. 20° C.
Silencer
32·7 Lb. per Sq. In. Abs. 1,045° F.
2·30 Kg. per Sq. Cm. Abs. 563° C.
Generator 1,500 R.P.M.
8,000 R.P.M.
Intermediate Pressure Turbine
Low Pressure Turbine
8,500 R.P.M.
Low Pressure Compressor
Starting Motor
Reduction Gear Assembly
47·4 Lb. per Sq. In. Abs. 307° F.
3·33 Kg. per Sq. Cm. Abs. 153° C.
64·4 Lb. per Sq. In. Abs. 1,279° F. 4·53 Kg. per Sq. Cm. Abs. 693° C.
46 Lb. per Sq. In. Abs. 122° F.
3·23 Kg. per Sq. Cm. Abs. 50° C.
Secondary Combustion Chamber
Intercooler
17,000 R.P.M.
High-Pressure Turbine
High Pressure Compressor
Starting Motor
69 Lb. per Sq. In. Abs. 1,029° F. 4·85 Kg. per Sq. Cm. Abs. 554° C.
15·5 Lb. per Sq. In. Abs. 804° F. 1·09 Kg. per Sq. Cm. Abs. 429° C.
142·3 Lb. per Sq. In. Abs. 392° F. 10 Kg. per Sq. Cm. Abs. 200° C.
140 Lb. per Sq. In. Abs. 1,292° F. 9·85 Kg. per Sq. Cm. Abs. 700° C.
Heat Exchanger
Primary Combustion Chamber
To Funnel
14·7 Lb. per Sq. In. Abs. 495° F
1·03 Kg per Sq. Cm. Abs. 257° C.
(4511.B.)
"ENGINEERING"

Particulars of the operating conditions of the Mitsubishi experimental gas-turbine (of the type 2SC/IP/IRE) are given on this diagramatic arrangement.

The F.I.A.T. C757 S is a two-stroke crosshead engine with seven cylinders and a bore and stroke of 750 mm. (29½ in.) and 1,320 mm. (52 in.). It was described in a paper by Dr. Ing. A. Gregoretti. Supercharging is obtained by a turbo-charger in series with a scavenge pump driven from the crosshead. The engine is rated for an output of 7,700 h.p. at 125 r.p.m. corresponding to a mean effective pressure of 6·8 kg. per sq. cm. (98 lb. per sq. in.)

A subject about which little is known was discussed in a paper presented by Mr. J. F. Alcock of Ricardo and Company, Limited, in conjunction with Mr. J. V. B. Robson and Mr. C. Mash. This was the distribution of heat flow in high-duty internal combustion engines, and some results of work carried out on three different engines were given. They included one petrol engine and two Diesel engines and the range of tests covered both the normally-aspirated and supercharged conditions over a wide range of speeds and loads. Heat flow measurements on a number of engines suggested that the flow varied as some power of the fuel burnt: the power appeared to be 0·75 which agreed with other work. A value called the heat flux factor was adopted as a parameter and was defined as the local flux divided by the 0·75 power of the product of the gross fuel consumption and the piston area.

Heat flow measurement in the three engines was made by traversing thermocouples of the type developed by Ricardo's for this work, and "maps" were drawn to show the heat flows. It was found that in general the flux increases from bottom to top of the cylinder bore and radially inwards towards the centre of the head. Tests on the scale effect were inconclusive. All the work had been done with liquid cooling so nothing was known of any differences when vapour was used; nor was the effect of variation of the intake temperature known. Much more evidence was needed before any definite results could be drawn.

3—GAS-TURBINE EXPERIENCE

Japanese experiences in the gas-turbine field were given at some length in a paper written by Mr. M. Isogai, Mr. M. Fujisawa and Mr. H. Yoshii which described in detail tests carried out on an experimental gas-turbine of 2,500 h.p. made by the Mitsubishi Nippon Heavy-Industries Limited. The type of machine chosen was open-cycle straight-compound with three shafts and intermediate power take-off, a reheater, heat exchanger, and intercooler (2SC/IP/IRE according to N.G.T.E. nomenclature). Particulars are given on the accompanying diagram. Each of the units was subjected to separate trials which they passed successfully, but when the whole plant was run it was found that it failed to generate more than 520 kW. It was concluded that this was due to mismatching of the units and this was rectified in part by providing a by-pass from the outlet of the secondary combustion chamber to the inlet of the low-pressure turbine, with a throttle valve and a cooler to maintain the same conditions at the inlet as before. When this had been done the power turbine generated 1,320 kW in spite of wasting about 25 per cent. of the pressure gas through the by-pass. Under these conditions performance figures for the whole plant for an output of 1,200 kW were: high-pressure shaft 17,000 r.p.m.; intermediate (generating) shaft 8,000 r.p.m.; low-pressure shaft 7,000 r.p.m.; and overall thermal efficiency, approximately 27 per cent. The maximum temperature at the turbine was 750 deg. C.

The maintenance and operation of gas-turbines was the subject of a paper by Mr. H. Pfenninger of Brown, Boveri and Company Limited. The units he considered ranged from 1,600 kW to 27,000 kW and the experience had been gained over periods up to 34,000 hours running time. Fuels were blast-furnace gas, natural gas and Bunker C oil. Detailed figures were given for four installations, one (5,400 kW) at a steelworks, the second (1,650 kW) at a cement works in Venezuela, the third (5,000 kW) in a power station in Saudi Arabia and the last (13,000 and 27,000 kW) in a power station in Switzerland.

The steelworks machine was designed to run on filtered blast-furnace gas having a considerable dust content. Liquid fuel can also be used if necessary. The plant has run for 34,000 hours without any repairs or replacements except that some of the blades in the compressor had to be renewed as result of detectable erosion after 22,000 hours. This was probably caused by iron dust in the atmosphere. Earlier there had been a slight scraping of the blading of the furnace-gas compressor as a result of running at an excessively high temperature during extremely cold weather. The turbine itself showed no wear at all. Maintenance costs of the plant over the 34,000 hour period worked out at 0·030 Swiss cents per kWh and the total operating costs at 3·418 Swiss cents per kWh (approximately 0·674*d.* at the current rate of exchange). This figure includes an allowance for fuel of 5·4 Swiss francs per 10^6 kcal.

In the cement works in Venezuela the plant ran for a time on Venezuelan heavy oil, but the viscosity of this proved too high and so, for convenience, it was diluted with Diesel oil in the proportions of 60 heavy oil to 40 Diesel oil. The mixture has a very high ash content and is also rich in vanadium. On this fuel sets I and II, both of 1,600 kW, ran for three years, the blading being washed every 930 hours. Maintenance costs were about 0·035 Swiss cents per kWh. Two 5,000 kW sets were then added and the fuel changed to natural gas with the result that the replacements to the combustion chambers, which had accounted for about half the maintenance costs, were no longer needed. Costs for all four sets to date are approximately 0·021 Swiss cents per kWh. Set I had run for 27,547 hours up to March, 1956, set II for 26,436 hours, set III for 19,702 hours (including one period when it ran for 16,088 hours out of a possible 16,128 hours) and set IV for 7,727 hours.

The third of the plants described was the power station at Dhahran in Saudi Arabia. Again the fuel was natural gas with crude oil as the alternative. These sets have not been installed for very long but the first to be commissioned has run for over 15,500 hours without inspection. The air compressor for the second was not inspected till after 12,168 hours, when the output of the set had fallen by about 700 kW but was still within the guaranteed figure. The blades were found to have on them a deposit of sand and soot (the latter possibly from the flare of the refinery) and when this was cleaned off the output rose by over 600 kW. It may be added that the sets are kept running even during sandstorms. Operating costs for the station have been estimated at a total of 5·888 Swiss cents per kWh of which direct maintenance

T_{cc} Temperature of combustion gases, deg. C.
T_w Temperature of tube wall, deg. C.
T_T Temperature at turbine inlet, deg. C.
T_c Temperature at compressor inlet, deg. C.
T_{cw} Temperature of cooling water, deg. C.
S.F.C. Specific fuel consumption, gm/s.h.p./hr.
η_R Recouperator effectiveness, per cent.
η_{th} Thermal efficiency, per cent.
P_{HP} Compressor delivery pressure, kg. per sq. cm.
σ_t Air-heater tube stress, k.g. per sq. cm.
Σ_ϵ Total circuit pressure losses, per cent.
Σ_t Combustion chamber tube life, 1,000 hr.

Performance curves for a 10,000 s.h.p. marine closed-cycle air turbine plotted against a base of power output.

(parts and wages) accounts for 0·096 cents—approximately 1·8 per cent. of the fuel costs.

In the power station in Switzerland, the last installation to be described, there are two sets, one of 13,000 kW capacity and the other of 27,000 kW; both run on Bunker C oil. Running hours are 14,078 and 11,630 respectively. The sets shut down at weekends and the blading is periodically washed (with tap water) to remove the deposit. After the washing the output is completely restored. So far set I has been washed about 60 times and set II about 50 times. Set I has also experienced 835 starts and set II, 700, a feature that is bound to increase maintenance costs. Very detailed figures for this station are available. They show that the total maintenance cost for set I has been 0·1108 Swiss cents per kWh and for set II 0·0826 cents per kWh.

Mr. Pfenninger emphasised that the choice of blade material was quite as important as the choice of fuel or additive from the corrosion point of view. He also warned that some additives varied considerably in their effect over the working range. (The influence of additives was dealt with fully by Mr. W. Tipler, of the Shell Petroleum Company in a subsequent paper). The washing system had proved quite satisfactory: washing of the blades was carried out *in situ* by spraying water on to them from a ring of nozzles in the casing, at the same time as the turbine was being rotated by the starter motor. The used water and the ash were collected from a drain.

CLOSED-CYCLE TURBINE

Developments in the field of the closed-cycle gas-turbine were outlined by Dr. Ing. W. Spillmann of Escher Wyss A.G. He described a 10,000 s.h.p. prototype plant that is under construction by the Mitsui Shipbuilding and Engineering Company for marine use. Since external firing is used for the air heater, the plant is almost independent of ambient conditions. An interesting feature is that the peak efficiency of 27 per cent. is expected to occur at about 10 per cent. full load, falling to 19 per cent. at full load. The design of the air heater was for a volume heat load of 180,000 B.Th.U. per cub. ft. per hour. As a result of the almost constant cycle temperature, the compressor-turbine unit runs at an almost constant speed of 8,700 r.p.m. for cruising conditions. The high pressure level in the cycle gives low suction volumes for the compressor and therefore a three-stage radial type is used. The four-stage high-pressure turbine has an outlet diameter of 480 mm. and an expansion ratio of 2 : 1. The remaining expansion, with a ratio of 1·6, takes place in the power turbine which has three stages and is designed for a maximum speed of 7,700 r.p.m. Performance curves are given in the figure.

The starter motor for this plant is an air motor supplied from the compressor that is used to make up the air losses of the cycle. Alternatively it could be driven electrically. The power required is approximately 100 h.p. at the shaft with a make-up compressor of 150 h.p. The time of starting is not known but is estimated to be from 2 to 3 hours depending mainly on the heaters. The starter motor itself would be running for about half an hour. Experiments on the heaters have so far been confined to Diesel oil. As regards the weight of the complete plant, Dr. Spillman gave the following figures. Turbine, starter and reduction gear 25 metric tons; heat transfer exchanger, etc. 28 tons; air heater pumps etc., 62 tons; pipework 10 tons; auxiliaries 6 tons; shafting etc., 130 tons: propeller 10 tons; giving a total engine weight of 131 tons or about 31 lb. per s.h.p.

AMPLIFIER FOR RADIO ASTRONOMY

A new solid-state microwave amplifier using a ferrite material as the active element has been successfully operated at Bell Telephone Laboratories, 463 West-street, New York 14. Although still in the laboratory stage, this amplifier is an important addition to the growing family of solid-state devices. It operates at room temperature, and is expected to have a much lower noise level than conventional microwave amplifiers. Thus it has exciting possibilities as an amplifier for very weak microwave signals such as may be encountered in the fields of radio astronomy, microwave relaying and radar.

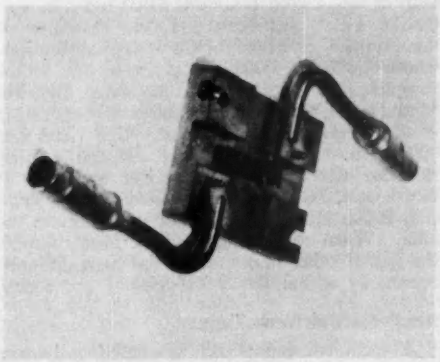


Fig. 1 Part of the microwave cavity used to produce amplification and oscillation within a ferrite is shown. The technique promises to lead to microwave amplifiers with very much reduced internal noise levels.

The amplifier has certain superficial similarities to the solid-state spin oscillator (ENGINEERING, page 362, March 22, 1957). Both types must be supplied with power from an oscillator operating at a higher frequency than the signal to be amplified. However, the principles of operation of the two devices are quite different.

In principle, the present device requires that a ferrite sample be placed in a microwave cavity which is simultaneously resonant at two signal frequencies. Microwave power at a frequency equal to the sum of the two signal frequencies is then pumped into the cavity. This power is analogous to the direct-current power supply of conventional electronic amplifiers. A fixed magnetic field, properly oriented and of sufficient intensity to cause gyromagnetic resonance within the ferrite at this sum frequency, must also be applied. Through non-linear coupling in the ferrite, amplification or oscillation will be exhibited at either the of lower frequencies. Alternatively, frequency conversion of a microwave signal can take place between these two frequencies.

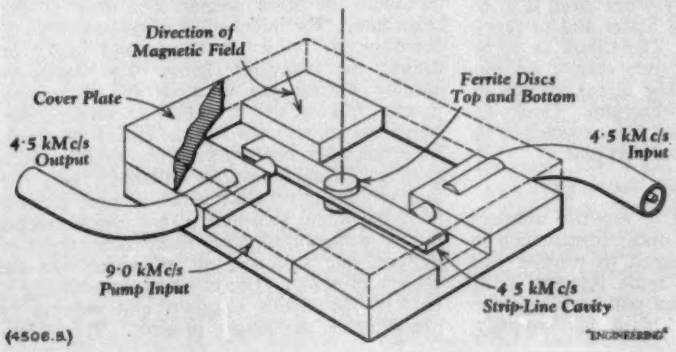


Fig. 2 In the experimental ferrite microwave amplifier the source of power is the 9,000 Mc/s input. Amplification occurs at 4,500 Mc/s.

One experiment conducted at Bell Laboratories is indicated in the diagram. To simplify the circuitry, the two signal frequencies were each made approximately 4,500 Mc/s. The pumping power of 9,000 Mc/s was fed into the resonant cavity as shown, and the signal power taken in and out by means of coaxial cable. With sufficient pumping power, oscillations took place at 4,500 Mc/s. When the pumping power was reduced somewhat, amplification was observed at 4,500 Mc/s.

In the experimental equipment, the magnetic field (about 2,500 gauss) was provided by an electro-magnet, but a permanent magnet could be employed if desired. The field is parallel to the plane of the strip-line cavity and oriented at an angle of about 45 deg. with the cavity.

In another experiment, a cavity was designed to be resonant at the two frequencies—4,000 and 4,800 Mc/s. The pumping frequency was set at 8,800 Mc/s. Oscillations and frequency conversion were observed at both the lower frequencies.

The action of the ferromagnetic amplifier can be simulated at low frequencies by a pair of ordinary resonant circuits coupled by a variable inductance or capacitance. Since certain very high frequency atomic phenomena also have this circuit analogue, it is possible that the same amplification principle will find applications at frequencies much higher than those presently in use. It appears that ferromagnetic amplifiers can be designed for operation in practically any portion of the microwave spectrum. Preliminary results indicate that the bandwidth is adequate for many applications. The ferromagnetic amplifier was predicted on theoretical grounds by Dr. H. Suhl. The experimental programme was carried out by Dr. M. T. Weiss.

* * *

WATER TRANSPORT

H.R.H. the Duke of Edinburgh said that the most important question to be discussed at the current meeting of the International Navigation Congress was that of the improvements which could be made in the handling of general cargo between a vessel and the storage installations on the quay or between the vessel and the means of inland transport. Such handling problems, he pointed out, occurred at both ends of every sea route.

Prince Philip was giving the opening address of the XIXth Congress which began on Monday, July 8, and is being held in the buildings of the Institution of Civil Engineers. The 1,000 or so delegates, who represent some 45 countries, were welcomed by the Duke and later Lord Waverley, who presided, told them that they faced a week of "serious and intense work." The technical work of the Congress has been based on over 100 papers on eleven subjects presented from 24 countries. The subjects to be discussed included, besides that already mentioned on handling cargo between ship and quay, berthage for the new super tankers, methods of preventing or reducing pollution of harbour waters by oil, evolution of craft or trains of barges for use on rivers and canals, siltation problems and harbour construction problems generally.

Of the 18 congresses held since the founding of the Permanent International Association of Navigation Congresses in 1885, only two have been held in the United Kingdom. The first was in Manchester in 1890 and the second in London in 1923. The organising committee for the present congress includes representatives of the Ministry of Transport and Civil Aviation, the Docks and Harbour Authorities Association, the Chamber of Shipping, the Institution of Civil Engineers, the Association of Consulting Engineers and the British Transport Commission. Also assisting are representatives of public works contractors and the petroleum industry

ATOMIC REVIEW

Material Evidence

EVIDENCE is widespread that materials are the controlling factor in atomic energy development; few problems do not arise in the first place from a limitation imposed by the materials available. Various aspects of materials technology form the subjects of the following notes.

Separating Zirconium

An Australian process for separating hafnium from zirconium has recently been described by Mr. Charles Lynch. The process is reported to have created much technical interest, and an option to buy overseas rights has been taken by an American firm, the U.S. Industrial Chemical Company, a division of the National Distillers and Chemical Corporation. The process was developed in Melbourne, Victoria, by the Industrial Chemistry Division of the Australian Commonwealth Scientific and Industrial Research Organisation. The Organisation operates on funds provided by the Australian Government.

Zirconium is produced from Australian black sands, an industry which is now increasing its production on the east and south-west coasts of the continent. Certain types of nuclear reactors, particularly those used in nuclear-powered naval vessels, require considerable quantities of zirconium, which must be free from hafnium, for fuel-element canning. Zirconium and hafnium behave generally in the same way in most conditions but they differ in one important respect: hafnium has a high neutron absorption whereas zirconium's is low. Since neutron economy is a major consideration in reactor operation the zirconium used must be free from hafnium. It is stated that the new Australian process considerably reduces the cost of the hafnium-free product, in comparison with the present method of solvent extraction.

Basically the new method involves separation of zirconium and hafnium tetrachlorides by preferential reduction of the zirconium to the trivalent state. The broad outlines of the method developed at C.S.I.R.O.'s Division of Industrial Chemistry involve firstly the conversion of zircon sand into zirconium carbide. This is performed by heating the sand with carbon in an arc or graphite-resistor furnace. The carbide is then transferred to a closed reactor having a cooled lid. Chlorine gas is passed over the heated carbide, and reacts with it to form zirconium tetrachloride. The cooled reactor lid condenses the tetrachloride vapour, which is transferred to a second reactor containing powdered zirconium metal. Heated under vacuum, the solid zirconium tetrachloride then sublimes. It reacts with the powdered zirconium and is reduced to the trihalide. There is no reduction of the hafnium tetrachloride and, as the reactor cools, the tetrachloride condenses on the lid. The zirconium trihalide collects as a solid at the bottom of the reactor, together with any unreacted zirconium metal that remains.

The lid containing the hafnium-rich chloride is replaced with a clean lid and the solids are reheated under vacuum. This step disproportionates the zirconium trihalide, partly to the tetrahalide, and partly to involatile dihalide. The tetrahalide is then removed for final processing to the pure zirconium metal. The dihalide remains behind with any powdered zirconium which has not reacted. This residue is not wasted but is used as the reducing agent for the next batch. The cycle of reduction, sublimation and disproportionation can be repeated indefinitely using a fresh batch of crude tetrachloride for each reduction. The reactor furnace is shown in Fig. 1.

Fig. 1 A process for separating zirconium from hafnium has been developed in Melbourne, Australia. Zirconium is used as a fuel canning material. A furnace is used in the process and the furnace lid, which contains cooling coils, is shown being adjusted.

Indian Thorium Deposits

Dr. Homi J. Bhabha, chairman of the Indian Atomic Energy Commission, has recently given details of India's deposits of fissile and fertile materials. It has been known for some time that established reserves of uranium and thorium in India are at least 15 times as great as coal and oil reserves in terms of energy value. An important discovery last year by the Raw Materials Division of the Department of Atomic Energy has more than doubled that figure. This deposit, on the Ranchi Plateau in the state of Bihar, lies within 10 ft. of the surface and contains over 3,000,000 tons of thorium in a concentration of over 10 per cent. and over 15,000 tons of uranium in a concentration of over 0·3 per cent. It is considered that these are conservative figures and that more deposits remain to be discovered. Deposits of thorium on the Travancore coast, considered one of the richest deposits in the world, are believed to be much smaller than the new source. Large deposits of uranium ore have also been found in Rajasthan and the North-East Frontier area. A survey of India's atomic energy programme appeared in Atomic Review last January 18.

Testing Mixed Fuel Lattices

It has been reported in *India News* that in order to utilise India's large reserves of thorium a zero energy reactor (ZERLINA) is to be built at Trombay at a total cost of Rs. 4 million (including the cost of heavy water which is to be imported from the United States and of fabricated natural uranium). ZERLINA is to be used for studies leading to new reactor designs, and particularly those using mixed lattices of uranium or plutonium and thorium. Designing of the reactor has begun and it is expected to be in operation by the middle of next year.

Materials Plants

A uranium metal plant to produce uranium metal of nuclear purity is under construction in India. The plant is expected to provide fuel elements for the Canada India Reactor (CIR) and ZERLINA. This plant will be in addition to the thorium-uranium plant at Trombay, which produces thorium nitrate for the gas-mantle industry. The capacity of Indian Rare Earths Limited, Alwaye, which processes the Travancore monazite sands, is to be doubled to 3,000 tons of monazite per annum. Steps are also being taken to establish plants for the production of atomically pure graphite and beryllium oxide. Beryllium oxide is considered a suitable moderator for small atomic power stations with outputs from 5,000 to 30,000 kW, the range in which a graphite-moderated reactor would be uneconomical.

A heavy-water separation plant is being established at Nangal in conjunction with a proposed fertiliser plant.

A plant for producing zirconium is also contemplated and provision for this has been included in the current year's budget. In addition, a pilot plant has just been completed at Ghatsira to extract small amounts of uranium contained in tailings from the plant of the Indian Copper Corporation.

Power for Canadian Uranium Mines

One of the most extensive mining projects in the world is the development of the Blind River uranium area in Canada. In little over three years since the first claims were staked, two mines are in production, and a further nine mines are in the course of construction or scheduled to start this year. Planned total capacity of these eleven mines is some 35,000 tons of ore a day. Total expenditure on the whole area is expected to be in the region of 300 million dols. The Blind River area, which was virtually virgin country three years ago, is on the shore of Lake Huron.

It is important during the processing of the ore that there is a full power supply all the time. Part of the chemical treatment of the crushed ore, known as leaching, particularly requires that the power supply should be maintained throughout the process. Should the power fail, the large tanks in which the ore is being treated become practically solid in a few minutes. Thus, as each new mine is constructed, standby generating sets are installed to provide emergency power should any part of the elaborate ore-treating processes be put out of action by power failure. A Mirrlees JVS12 925 kW 900 r.p.m. unit has recently been installed at each of the Algom Uranium 3,000 ton mines at Quirke Lake and Nordic Lake. Another of these units is on order for Can-Met Exploration, whose 2,500 to 3,000 ton plant is due to be completed in April. At Consolidated Dension Mines, one 5,700 ton plant is due to start operating in the spring, and a Mirrlees JVS12 1,200 kW 900 r.p.m. unit is now being installed. Other Mirrlees sets in the Blind River area are at Northspan, Stanrock and Stanleigh. The Dension is the most impressive of the mines in the area. When completed it will be nearly double the size of other mines and it has been designed eventually to handle 10,000 tons of ore a day.

Irradiated Polythene Tape

A technical report on irradiated Polythene tape has recently been published by Tube Investments Limited, The Adelphi, London, W.C.2. All plastics are composed of long chains of atoms linked together by primary bonds. The electrons or radiations used by TI to treat the plastics have energies many thousands of times greater than that of the chain link. The initial effect of the radiation is, therefore, to break the bonds and undo, or dislink, the molecular chains. The fragments initially formed are unstable and a healing process follows. In this healing process, the fragments are relinked and the chains reformed. In certain cases, new types of links result between chains. These, known as crosslinks, give rise to a molecular structure which is more durable than the initial structure. This useful process occurs with polyethylene, many other types of plastics, and silicones, all of which are the subject of study. The effect of crosslinking is to knit the chains together, and melting or dissolving is no longer possible. Thus high-

MECHANICAL PROPERTIES OF VARIOUS GRADES OF IRRADIATED POLYETHYLENE

Type	Thickness (mils)	Tensile strength (lb. per sq. in.)			Elongation at break			Shrinkage lengthwise (per cent.)	Seal strength at 20 deg. C., lb. per in. width	
		20 deg. C.	100 deg. C.	125 deg. C.	20 deg. C.	100 deg. C.	125 deg. C.		Butt*	Lap†
OGO2 ..	2	3,150	650	450	400	200	150	40	3·3	6·7
AGA2 ..	2	2,600	800	300	250	200	150	30	3·7	5·2
AGB5 ..	5	1,900	500	100	550	500	400	20	3·0	6·0
BGA2 ..	2	2,800	800	300	300	250	150	30	3·0	5·3
BGA5 ..	5	1,800	600	150	550	550	400	20	4·4	6·9

* Figure for unirradiated film = 3 to 5 lb. † Figure for unirradiated film = 5 to 7 lb.

energy radiation converts many thermoplastics into thermo-setting materials. One of the distinctions between thermosetting plastics and thermoplastics is the improvement brought about by the presence of fillers, as for example in vulcanised rubber or phenol-formaldehyde resins, and this property is also shown by crosslinked polyethylene. The difference in the structure of normal and crosslinked polyethylene is shown diagrammatically in Fig. 2. An example of the qualities introduced is provided by irradiated polyethylene cable, which can be

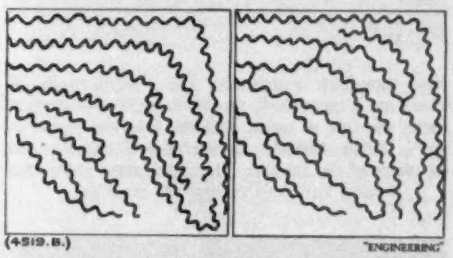


Fig. 2 Effect of irradiation on polyethylene, showing diagrammatically the phenomenon of cross-linking. (Left) structure of un-irradiated polyethylene—chains can be separated. (Right) structure of irradiated polyethylene—chains are inseparable.

placed in molten solder at 300 deg. C. without obvious deterioration.

Three general forms of irradiated tape are mentioned in the report, which explains the chemical and physical principles of the process and lists properties and applications of the materials. Type OGO material is suitable for packing and protective wrapping; AGA is intended for electrical applications; and BGA is similar to AGA but offers even greater resistance to oxidative deterioration and prolonged exposure to weathering and sunlight. For all three, water absorption is negligible, chemical resistance except to nitric acid very good, and solvent resistance good below 60 deg. C. They are swollen by certain hydrocarbons and halogenated hydrocarbons above 60 deg. C. Power factor (60 to 10^{10} c.p.s.) is 0·0004, volume resistance 10^{16} ohm-cm., and dielectric constant 2·3. Their mechanical properties are given in the above table.

Criticality in Chemical Plants

In a mass of fissile material spontaneous fission is continually occurring with emission of neutrons, but a chain reaction cannot be set up unless at least one of the neutrons emitted when a nucleus undergoes fission causes fission of a further nucleus. Thus a mass of fissile material is said to be critical when its mass or shape is such that the proportion of neutrons which escape from its surface is sufficiently small for a chain reaction to be established within the mass. Criticality is a term most often associated with nuclear reactors, but it is also of the greatest importance in the design and operation of chemical plants for processing fissile materials. Thus, if a solution of fissile material were allowed to evaporate so that the concentration were increased, the solution might become critical with disastrous results. Dilution with a moderator such as water, or the use of a water-jacket condenser (acting in this case as a neutron reflector) might cause a similar effect. Even the approach of a human body (an organic moderator or reflector) might bring about criticality; and to load sub-critical quantities of fissile material into a motor vehicle so that they lie close to an oil drum could also give rise to critical conditions. Shape is also an important consideration, and a safe quantity of a fissile solution in a long narrow column or pipeline might become dangerous if poured into a spherical vessel.

Precautions are therefore of paramount importance in a processing plant for reactor fuel elements. Vessels whenever possible are in the form of flat slabs, and even the swarf obtained from machining plutonium, say, is carefully collected. It has been suggested that the criterion for designing a chemical plant of this kind is that it should remain safe even when filled to the roof with oil. (Oil, which consists mainly of hydrocarbons, is of course an excellent moderator, though its instability at high temperatures makes it unsuitable for use in reactors.) A rule observed at United Kingdom Atomic Energy Authority's works is that plutonium be processed on benches and carried on trolleys all at the same level—as if it were contained within a vast horizontal slab.

There are thus five factors to be borne in mind in designing chemical plant for fissile materials: (1) mass, (2) concentration, (3) presence of moderators, (4) presence of reflectors, and (5) shape. There is also a sixth consideration, though it will be evident that such a situation would seldom if ever be permitted to arise in a chemical plant: a super-critical mass might be safe in the presence of neutron absorbers but become critical immediately they were removed. This condition is important, however, in the context of reactors. Many of these points are clearly and forcefully made in a stimulating colour film, "Criticality," recently produced for the Atomic Energy Authority, and a research group concerned solely with the study of criticality is active at Dounreay.

Fuel Element Radiography

The feasibility of inspecting fabricated nuclear reactor fuel elements by means of gamma radiography has been demonstrated in a series of experiments conducted at the Battelle Memorial Institute, Ohio, for the United States Atomic Energy Commission's Westinghouse operated Bettis Laboratory. Using a line radiation source of tungsten 185 wire, a technique has been devised for obtaining gamma radiographs of the separate plates of an assembled parallel-plate fuel element. Five of the tungsten wires are placed in an aluminium holder designed to fit the fuel-element coolant channel. The holder is inserted in a coolant channel and X-ray film is placed in the adjacent channels, thus enabling inspection of two fuel plates at 1½ hour intervals. The radiographs reveal the core necking and alloy edge and also defects in the core.

The technique has been devised in order to determine the position of the core, defects in the bonding of the core edge to the cladding, and, if possible, core, and thickening and necking in a multi-plate assembly. Conventional radiography holds little probability of providing adequate sensitivity, since the pictures have to be taken through a number of plates formed as unit. Initial theoretical studies indicated that isotopes of thulium and tungsten might be the most promising sources for fine-line gamma radiography. Experiments have shown that thulium is an excellent source except for the non-uniformity of radiation caused by uneven wire fabrication. Until a technology of thulium-wire fabrication is developed, the use of thulium as a line source will not be practicable. Tungsten wire of the required diameter is available commercially and has proved to be the most practical radiation source even though gamma radiation energy characteristics are not quite as suitable as those of the thulium isotope. The tungsten source requires a very high thermal neutron flux for sufficient activation and its gamma-ray photons have higher than optimum energy for this particular task.

Finned Tubes

A revised edition of their booklet on "Integron" finned tubing has recently been issued by the Metals Division of Imperial Chemical Industries Limited, P.O. Box 216, Birmingham 6. Heat-transfer data and other details are given for high and low-fin tubing and bi-metal tubing. Both high and low-fin tubes are recommended for the nuclear power industry as heat-exchanger tubes and reactor fuel cans. Various forms of Integron tubing are illustrated in Fig. 3.

R.S.A. Medal

The gold Albert Medal of the Royal Society of Arts has been awarded for 1957, with the approval of H.R.H. The Duke of Edinburgh, President of the Society, to Sir Christopher Hinton, K.B.E., F.R.S. The citation notes Sir Christopher's "outstanding leadership in nuclear power development."

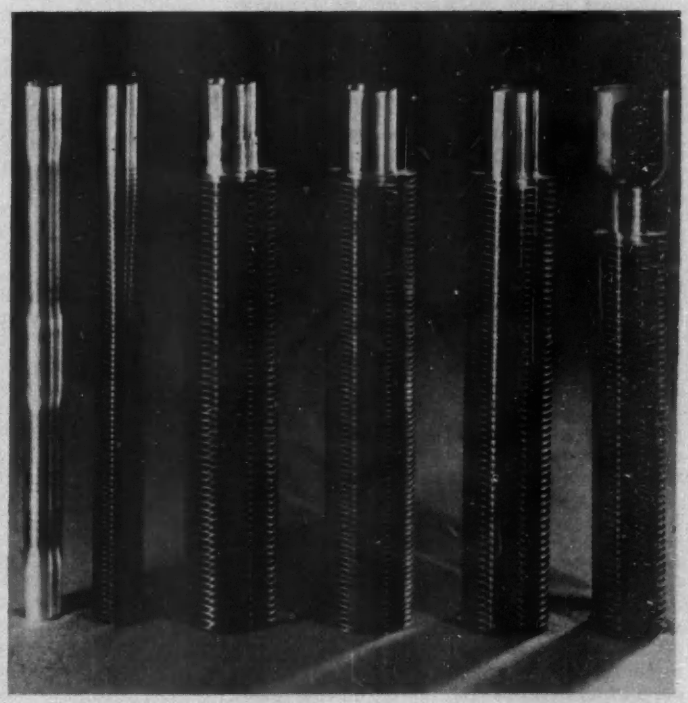


Fig. 3. Integron integral finned tubing has been recommended for the nuclear power industry as heat-exchanger tubing and reactor fuel cans. Low-fin, high-fin and bi-metal tubes are shown with various end finishes.

MILLION GALLON PAINT STORE

AUTOMATIC MECHANICAL HANDLING

In order to solve urgent storage and dispatch problems created by increasing demands for their paint products, Imperial Chemical Industries Limited, Paints Division, have built, at their Slough headquarters, Buckinghamshire, a warehouse having an ultimate capacity of 1 million gallons. This warehouse, which is now in operation and accommodates a working stock of 800,000 gallons of paint products, incorporates the latest mechanical-handling equipment and has already effected economies in distribution and storage.

Two features of the new warehouse are of particular interest. In the first place, it was decided that the 1 million gallons of paint required to ensure sufficient stocks for prompt service would necessitate a four-storey building on the site available, which measures 400 ft. by 330 ft. The high loads resulting from such a quantity of paint stored on shelves would have made conventional building methods uneconomic and the procedure adopted has been to build 40 ft. high storage racks and suspend the three upper floors from these racks. Thus, the entire weight of the four-tier storage racks of the warehouse rests on the ground and not on intermediate floors and the outside walls of the building are mere shells, all the weight being taken through the thousands of vertical members of the racks. The four-storey installation of steel shelving is shown in course of erection in the upper right-hand illustration. The contractors for this work were Constructors Limited, Tyburn-road, Erdington, Birmingham, 24.

The second feature of interest in connection with the new warehouse is that the finished products are moved from the container-filling department of the factory into one end of the warehouse, and from the collection points in the warehouse to the various dispatch points at the other end of the building by a " Stanrun " overhead chain-conveyor system which carries the products not only horizontally but also vertically to the upper floors as well. The contractors for the Stanrun system with its suspended trays were George W. King Limited, Stevenage, Hertfordshire.

It is of interest to note, that a total of some 7,000 stock items of paint products have to be maintained readily available by the Division and that the demand for most of these fluctuates considerably according to the season, and even according to the weather. Moreover, orders from individual clients may vary from a few pints to hundreds of gallons.

The overhead chain-conveyor system, which travels at a speed of from 40 to 45 ft. a minute, has a total length of 3,000 ft. and it utilises trays suspended from trolleys running on the chain. Each tray can carry up to five gallons of paint. The tins of paint from the filling machines are loaded on to trays and a control key on the trolley is set according to the floor of the warehouse for which that particular tray is intended. The tray is then shunted off automatically at the correct floor and, on arrival at the destination, the tins are stacked on the appropriate shelves, by hand, according to their type, size and colour. A view of trays of tins of paint proceeding from the filling department to the appropriate floor of the warehouse is shown in the lower right-hand illustration.

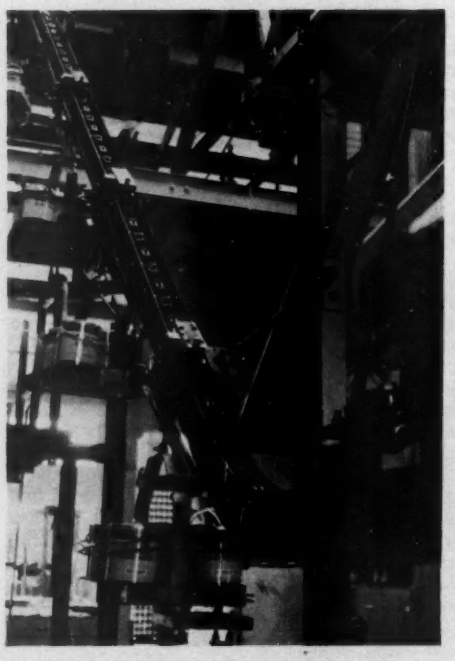
To assemble orders in the four-floor warehouse and deliver them to the marshalling area, which is on the ground floor at the end of the building opposite to that receiving tins of paint from the filling department, the overhead chain-conveyor system extends along the central gangway on each floor level. The warehouse is divided into zones, each of which has an assembler responsible for making up orders, or part orders, relating to the type of paint stored in his zone. The assembler receives his instructions from the conveyor operator by a pneumatic-tube system supplied by Lamson Engineering Company, Limited, Hythe-road, Willesden, London, N.W.10. Then, using a light specially-designed hand trolley incorporating a step ladder, he collects the different items specified on the order sheet and finally loads them into an empty overhead-conveyor tray which will be waiting in the nearest loading station. There are six of these loading stations on each of the four floors. Having loaded the tray, the assembler adjusts the keys on the conveyor trolley to the appropriate combination so that they will be selected by the transfer machine at the entry to his own particular marshalling line; there are eight marshalling lines at the end of the conveyor system. He writes the sequence number of the order on a metal flag provided on the conveyor tray and pulls a lever to dispatch the loaded tray. This is then automatically elevated and put back into the main circulating-conveyor system. The next empty tray is then selected by the loading station automatically and brought down to loading level.

After the assembler has completed his part of an order he returns the document by pneumatic tube to the control position, where its receipt signifies that the goods are on the move on the conveyor system. Each loaded tray automatically reaches its selected marshalling line. At the same time, other trays relating to the same order will be arriving on other marshalling lines from the other assemblers. When the order is complete, the conveyor operator sends all the trays from the marshalling lines off on to a transfer conveyor. This takes the trays to storage loops where they circulate in a manner recalling somewhat the system of " stacking " aircraft waiting to land on a crowded airport. When their turn comes, the trays come down to the checkers who unload the tins on to a roller track.

The tins are then packed into cartons of which there are 14 sizes, unless the order is for local delivery when the tins are sent out singly without extra covering. The filled cartons and tins proceed along the roller track being labelled *en route*, to a point where they are removed on to a stillage or mobile rack unit. Large orders are accumulated on stillages and are taken out of the building and loaded direct on to lorries by elevating fork-lift trucks. Smaller orders are loaded on the mobile rack units and when full these are taken by lift truck to the appropriate vehicle-loading conveyor; there are six of these and they are of the slat-conveyor type, provided by the New Conveyor Company, Limited, Newcon House, Brook-street, Smethwick, 40, Staffordshire. On the arrival of the road vehicle for loading, the cartons or tins are placed on the conveyor, whence they are removed by an operator on the vehicle and stacked as required. A further distinct advantage is that the vehicle-loading conveyors are retractable and, by operating push-button controls, the operator can extend the conveyor out into the waiting vehicle thus minimising the effort required in loading and stacking.

The new warehouse serves the dual function of a distribution centre for clients' orders in the southern region of England and a depot from which products are distributed to other warehouses throughout the country. It is interesting to note that many economies in handling costs and in speed of dispatch have been achieved since the new premises were put into operation. We were informed, for example, that it is now possible to make up and dispatch, in 1½ hours, a complete order, packed for long-distance delivery, which by earlier methods took as long as 24 hours. Moreover, in the former one-storey warehouse used, the storage capacity, including the reception and dispatch areas, was 7 gallons per sq. ft. of floor space, whereas, in the new building, it is 30. Results to date show, in addition to a speedier flow of goods, a low capital cost per gallon of paint warehoused.

New four-floor warehouse, the outside walls of which are a mere shell, the 40 ft. high steel storage racks for tins of paint, and the intervening gangways, being entirely supported on the vertical members of the racks. The illustration shows the steel racks in course of erection.



Newly-filled tins of paint are received into the warehouse, and tins forming part of an outgoing order are dispatched by means of the overhead chain-conveyor system shown in the illustration. This has a total length of 3,000 ft., and by the setting of control keys on each trolley carrying a tray of paint on the conveyor, the tray is manoeuvred and shunted off automatically at the correct floor to its destination. The tins are taken off for storage or put on for dispatch by hand.

★ ★ ★

Aero Research Limited, Duxford, Cambridge, have produced a 16 mm. colour sound film describing the " Redux " bonding process. The film, which runs for 17 minutes, is available on loan in French, German, Italian and Japanese.

In Parliament

SEPARATING AIRCRAFT ON TRANSATLANTIC FLIGHTS

Last week, the attention of the House of Commons was drawn by Mr. John Rankin (Labour/Co-operative) to the fact that the number of transatlantic flights by aircraft was increasing and that there was some congestion of the airways as a result. He asked what changes were proposed in the vertical, lateral, and fore and aft separation standards, in order to enable more aircraft to be fitted into the available space.

In reply, Mr. Harold Watkinson, the Minister of Transport and Civil Aviation, announced that a long-range navigation system was now being tried, which should enable the lateral separation of aircraft to be reduced. This arrangement, coupled with improvements to existing communication facilities, should also effect reductions in fore and aft separation. No changes in the vertical separation of aircraft were contemplated. The extended use of radar techniques and improved methods of presenting information should enable additional traffic, including the new turbo-jet airliners, to be fitted into existing airport traffic patterns. Mr. Watkinson hoped that these techniques would simplify the work of the air traffic controller, in spite of the increased traffic involved.

PROFIT SHARING SCHEMES

Some interesting points regarding the development of profit-sharing and co-partnership schemes were unfolded as a result of questions put by Major Tufton Beamish (Conservative). On these matters, Mr. Robert Carr, the Parliamentary Secretary to the Ministry of Labour and National Service, stated that, in accordance with a resolution of the House on January 28, 1955, an inquiry had been made by his Ministry into such schemes in operation in 1954, with a view to providing up-to-date factual information about their working and development. Questionnaires had been sent to 1,800 undertakings and replies had been received from 1,680 of these firms, of which 408 operated schemes. An analysis of the schemes operating in 1954 had been published in the *Ministry of Labour Gazette* for May, 1956. No further inquiry had been made, but the Ministry would be prepared to consider holding another inquiry next year.

In 1954, nearly 381,000 employees were known to have been entitled to participate in profit-sharing and co-partnership schemes, other than schemes which applied only to staff or to other selected classes of employees. The corresponding figure in 1938 was 216,000. It was not possible to measure precisely the financial benefits from all schemes but, for the 349 schemes of a profit bonus type in 1954, which applied to the firms' employees in general and covered some 357,000 persons, the average amount of bonus per head was £28 5*s.* 4*d.* and the average addition to earnings amounted to 5·8 per cent. The corresponding figures for 1938 were 355 schemes, 238,000 persons, £11 6*s.* 7*d.*, and 5·9 per cent.

LIFE SAVING AT SEA

Requests for information from Mr. Watkinson regarding the issuing of further regulations in respect of the compulsory carrying of inflatable life-rafts on passenger and cargo vessels were put forward by Wing-Commander Sir Norman Hulbert (Conservative) and Captain H. B. Kerby (Conservative).

On this subject, Mr. Watkinson said that he was now preparing regulations requiring the carriage of inflatable life-rafts in cross channel passenger ships, in cargo ships engaged on coastal and short international voyages, and in sea-going tugs and other small sea-going craft. He was, he said, also recommending that inflatable life-rafts be carried by ocean-going dry cargo ships in addition to their existing life-saving appliances, pending the revision of the International Convention for the Safety of Life at Sea, 1948. These proposals had been discussed in detail with shipbuilders, shipowners and seafarers, who were all in agreement. Their ready co-operation in these measures would do much to improve still further the good safety record of British ships.

He told Captain Kerby that inflatable life-rafts which were approved for use under the Merchant Shipping (Lifesaving Appliances) (Amendment) Rules, 1956, could be thrown overboard and inflated in a matter of seconds, and gave protection out of the water and under cover. From such information as he had received, the Gaskin life-raft appeared more comparable to a lifeboat and he was not satisfied that it complied with the statutory requirements.

SUNDERLAND TECHNICAL COLLEGE

A statement regarding the further plans for Sunderland Technical College was asked for by Mr. Paul Williams (Independent Conservative), who pointed out that there was dissatisfaction about the decision of Lord Hailsham, the Minister of Education, on the naming of the College of Advanced Technology for the North-East.

Sir Edward Boyle, Bt., the Parliamentary Secretary to the Ministry of Education, said that the approved building plan for Sunderland Technical College for the current year included a hostel for about 50 students and a project, costing some £200,000, for accommodation on a separate site which would remove the lower-level engineering and commercial courses from the main buildings. The programme approved for 1958-59, included a £350,000 extension to the teaching accommodation of the main college and that extension should enable all the departments to expand. The Northern Advisory Council was due to consider, at an early meeting, the whole pattern of advanced technological education in the North East of England, in the light of Lord Hailsham's decision to designate a College of Advanced Technology there.

Electricity Single-Wire Earth Return

Further information was sought by Mr. W. M. F. Vane (Conservative) regarding the five experimental schemes employing the Lloyd-Mandeno single-wire earth return for electrical current. He was informed by Mr. Reginald Maudling, the Paymaster-General, that this work was being carried out by the electrical industry as a part of its normal programme of research and development. It would be, therefore, for the industry itself to announce the results. He had been informed, however, that these schemes—two in Dorset and one each in Buckingham, Somerset and Wiltshire—had so far been progressing satisfactorily. It was intended to bring a further seven schemes into operation before attempting to draw firm conclusions from the programme and the results were not likely to be available before next summer.

Capital Investment in Coal

Replying to Mr. Julian Ridsdale (Conservative and Liberal Unionist) about capital investment in the coal industry by the National Coal Board, Mr. Maudling said that the Board had spent about £387 million during the five years 1952 to 1956. As to any question of financing capital investments without raising coal prices, as was suggested, Mr. Maudling pointed out that even taking the recent prices into account, the Board had stated that it expected to realise only a fairly small surplus for 1957.

American Prospecting in Somaliland

Matters relating to the prospecting for oil by American firms in British overseas territories were raised by Mr. A. Creech Jones (Labour). He asked the Secretary of State for the Colonies to state the terms on which he proposed to grant prospecting and operating licences to Conoco Somal Limited (United States) and the Standard-Vacuum Oil Company (United States) for oil mining in Somaliland. Mr. John Profumo, Under-Secretary of State for the Colonies, said the Government of Somaliland Protectorate had granted licences to Conoco Somal Limited which followed generally the lines of the colonial model licences, and it was expected that similar licences would be granted shortly to the Standard-Vacuum Company.

Computers to Help the G.P.O.

Sir Keith Joseph, Bt. (Conservative) asked the Postmaster-General whether consideration had been given to the possibility of using an electronic computer in the Post Office. Mr. Ernest Marples replied that orders had been placed for two computers and associated equipment for pay-roll work in the Department. These instruments would be used initially to calculate the wages and salaries, and prepare pay-roll documents, for the 112,000 Post Office staff in the London Area. The Postmaster-General said he hoped that these computers would enable the Department to achieve an ultimate saving of about £100,000 a year.

A Fine Investment

Information about the British Government's holding in the British Petroleum Company, Limited, was sought by Mr. Harold Wilson (Labour), a former President of the Board of Trade. He was told by Mr. Nigel Birch, Economic Secretary to the Treasury, that the sum originally paid by the Government for their shares in that Company was £5,001,000. The value of the Government's holding at the close of business on Friday, June 28 last, was just under £462,000,000.

Population Movements in Middlesex

Mr. A. E. Hunter (Labour) pressed the Minister of Housing and Local Government to give serious consideration to the transfer of families in Middlesex to the new towns, saying that local authorities there had waiting lists of many thousands and that the situation was becoming serious. Mr. J. R. Bevins, the Parliamentary Secretary to the Ministry, replied that about one quarter of the total number of new tenants in the new towns last year came from the county of Middlesex.

Few Out of Work on Clydebank

It was pointed out by Mr. Iain Macleod, the Minister of Labour and National Service, in reply to a point raised by Mr. C. R. Bence (Labour), that there were 458 men and boys, and 106 women and girls, registered as unemployed in the burgh of Clydebank on June 17 last.

New Committee on Radio Frequency

Questions of radio frequency allocation were brought to the notice of the House by Mr. E. S. T. Johnson (Conservative). In reply, Mr. Ernest Marples, the Postmaster-General, stated that he intended to set up a new committee to advise him on the broad aspects of the problem. The committee would include representatives of industry and users, but its precise composition had yet to be settled.

Oil Pollution in English Channel

Difficulties arising from oil pollution of the sea were discussed in a question put to the Minister of Transport and Civil Aviation by Mr. James Callaghan (Labour). He asked for particulars of the size of the film that had formed on the surface of the sea from the oil tanker Stoney Point, and if there was any way of breaking up the film before it reached the coastline. Mr. Harold Watkinson said that, to the best of his belief, the ship's leak had been plugged. The vessel was then in the Antwerp area and he had had no reports of pollution during her passage up the English Channel. The film of oil that formed on the surface of the sea while the ship lay off Falmouth at the end of June was about six miles in diameter. The Minister added that he knew of no way of dealing with oil in the open sea.

THE HUMAN ELEMENT

An Expensive Forty Hours

With the decision of the miners last week to press for the 40 hour week, this question now looks like being the main national issue for the rest of this year between organised labour and the employers. The mining and engineering workers are behind it and the Transport and General Workers Union is expected to come down in favour of it in the next few weeks. Other, smaller bodies are also backing the demand for a shorter working week.

It is not yet apparent whether this sudden change of emphasis from wages to hours is mainly a question of tactics made popular by the engineering workers, or a long-term urge towards greater leisure. There is, however, danger that some union leaders, anxious not to price goods out of export markets by continually raising wages will take shorter hours as an alternative. Superficially this could mean a year of comparative peace in union-employer relations if the latter accept the idea of the shorter working week as something to be conceded now.

Obviously, a fall in working hours can be just as costly as higher wages and a much more serious brake on investment. At a time when expensive machinery for investment is under discussion, there is a serious snag to be faced if labour insists on working shorter hours and wants only a limited amount of overtime. In a period of full employment, it is difficult enough getting labour for single shifts. If employers are faced with shorter shifts for the same pay with some overtime, how are they going to react to the introduction of new expensive machines needing multiple shifts throughout the day and night to be efficient ?

Taking Inflation Seriously

The Chancellor of the Exchequer is to have further talks next week (July 17 and 18) with the representatives of employers and of the nationalised industries on the proposed impartial body on price stability and the standard of wages. These are in addition to the further talks already planned between Ministers and the T.U.C. This "second round" of discussions is evidence that the Government are in earnest and consider that a real possibility exists to set up a body which would make a useful contribution to this most intractable of problems. Adverse comment by union leaders on the proposed new body as envisaged by the Jack Report is thought to have been countered by greatly increasing the scope of the proposed organisation.

The Government have shown that they consider the problem of inflation a technical problem which can be solved by a technical approach. By showing their willingness to listen to impartial advice, as would presumably be given by the wage-price body they have in mind, they have gone far to marshal the support of leaders on both sides of industry. There is little doubt that a need exists for better information on economic trends and for the means of relating industry's prospects to the conditions prevailing at any one time.

This suggests that the new body will have to be provided with research facilities and with experienced staff to conduct the necessary investigations. To have a collection of representatives from both sides of industry and the government, fed with information from official sources would serve little purpose nor carry any real weight. The type of organisation required is one of sufficient status and acknowledged independence of outlook to win the respect and confidence of all concerned. The British Institute of Management meets at least some of the prerequisites, and has the advantage of having been established for over a decade on "technical" grounds, with the interests of both sides of industry as equal objectives.

Voluntary Arbitration

An interesting article on the use of arbitration in industrial disputes in the United States is included in the June 28 issue of *Labour News from the United States*. Curiously described as "impartial," voluntary arbitration is said to be "the capstone of the grievance settlement machinery in 85 to 90 per cent. of United States agreements." The sharing of its cost by both parties is normal practice and the heavy expenses involved tend to reduce its use.

The article quotes the results of an analysis made by the United States Bureau of Labour Statistics of all the disputes referred to arbitration between August, 1942 and June, 1952, in the 15 plants of the Bethlehem Steel Company. The United Steel Workers of America was the union representing the employees throughout the period. During that time 2,400 disputes were submitted to arbitration, but only 1,003 were settled by an arbitrator's decision (more than half were withdrawn).

Wage rate or job classification disputes were the most common of the grievances referred to arbitration, accounting for almost half the total. Included under these headings were individual workers' complaints that wage rates or job classifications were either not in accordance with plant practices or with the type of work performed. Another major classification of grievances, which accounted for about one-third of the total brought to arbitration, related to worker status, such as seniority in lay-off, promotion, filling of temporary vacancies, etc. The fact that only about one-fifth of all the grievances brought to arbitration were decided in favour of the workers involved, and half in favour of the company—while arbitration continues to be regarded by all concerned as a fair way out of a dispute—suggests that the arbitrators enjoy the respect of both sides.

Industrial Passport

In his paper "The Challenge of the 'Dip. Tech.'" presented at Harrogate (see page 38) Sir Walter Puckey discussed the significance of the new Diploma in Technology award: the first final examinations for the new diploma will be held by the Birmingham College of Technology in about June of next year. During the following two or three years, probably 20 or more approved technical colleges will be preparing students for similar examinations in engineering and other technologies, leading to the same award.

Sir Walter considers that the Dip. Tech. award will be "an industrial passport for an increasing number of promising young men who have just completed a four or five years' course (usually sandwich) at good university standards." His paper examines the essential prerequisites "required to be recognised by us, now, if our management succession is to be assured." One of these is that to-morrow's technologists and managers must be able to produce not only more new knowledge, but more goods embodying new knowledge. Progress in British industry will depend to an increasing extent on the ability of new generations to translate ideas into practice more effectively. There must be a greater integration of knowledge within individuals and a greater use of teams. The growth of new specialist fields, such as nucleonics and cybernetics, calls for not only greater numbers of scientists but for the integration of "their uncommon tasks into a common goal."

This is one of the tasks which the National Council for Technical Awards (under the chairmanship of Lord Hives) have before them. Another is the raising of the status of technical colleges, and of those who hold their degrees to a level comparable with the better university degrees, and Sir Walter looks to the new national Diploma as "one of the best opportunities likely to be presented for increasing the stature of the colleges."

Dearth of Servants

The Civil Service Commissioners have now issued their report for the year ended March, 1957. Comment is made once again about the difficulty in maintaining the necessary flow of recruits up to the standard set. There seems to have been some improvement on the position in 1956, however. The improvement is general—from typists to candidates for the administrative grade. A variety of causes seem to have contributed towards this—mainly shorter hours and a widening of the base of recruitment.

In the scientific classes the method of continuous open competition is still the only method of recruitment. The Commissioners comment on the fact that it seems easier to recruit for Senior Scientific officers than for Scientific Officers. The largest deficiencies occur in Assistants (Scientific).

Among the professional and technical classes, the general state of recruitment is not good and the position of engineers is particularly disappointing. The worst shortages last year were in the civil and electrical fields, communications engineers being especially scarce. In the competition for mechanical and electrical engineers a higher proportion was interviewed than is usually the case but the return on this additional work seems to have been poor. Altogether, the Civil Service still feels the competition from trade and industry. The position seems slightly better lower down the scale but there is plenty of room for improvement in the higher grades if the Civil Service is to get its share of the good and the best.

Dull as Dockwater

The annual report and accounts of the National Dock Labour Board for 1956, is not a very inspiring document, though there seems to be no reason why this should be so. Whatever complaints about their work which men connected with dock labour may be driven to make, one of them is certainly not that it is dull. But in the annual reports, the lay reader is as wise after his conducted tour of the statistics as he was when he started. No oasis in the arid march is to be found in the form of a summary or a brief recapitulation of the year's events and overall prospects. It reads like a document about dockers for dockmen. This is a pity, for the industry is a vital one and it has often had less than understanding treatment from the general public.

There is a good example of the layman's problem of understanding the industry's progress in the first appendix. This shows the trend of employment compared with volume of trade. It is noticeable that although the index of imports and exports rose in the third and fourth quarters of last year the index of turns worked, excluding overtime, fell. This was in contrast with a year before when normal turns worked responded quickly to rising trade. Anyone wishing to follow this interesting contrast through is faced with a time-consuming search into definitions and into the other appendices. The docks deserve as much informed publicity about their affairs as the other major industries and preparation of the annual review to attract a wider public might help toward this end.

ENGINEERING

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